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[Document Name] Description

[Title of the Invention] DEVICE FOR OPTICAL COMMUNICATION, AND MANUFACTURING METHOD OF DEVICE FOR OPTICAL COMMUNICATION

[Scope of Claims for Patent]

[Claim 1] A device for optical communication comprising:

a substrate for mounting an IC chip on which at least an optical element is mounted; and

a multilayered printed circuit board on which at least an optical waveguide is formed,

the device for optical communication being constituted to be able to transmit optical signal between said optical waveguide and said optical element,

wherein

a sealing resin layer is formed between said substrate for mounting an IC chip and said multilayered printed circuit board.

[Claim 2] The device for optical communication according to Claim 1,

wherein

said sealing resin layer has a transmissivity of 70 % or more for communication wavelength light.

[Claim 3] The device for optical communication according to Claim 1 or 2,

wherein

said sealing resin layer contains particles.

[Claim 4] The device for optical communication according to any of claims 1 to 3,

wherein

said optical element is a light receiving element and/or a light emitting element.

[Claim 5] A manufacturing method of a device for optical communication,

wherein

after separately manufacturing a substrate for mounting an IC chip on which at least an optical element is mounted, and

a multilayered printed circuit board on which at least an optical waveguide is formed,

said substrate for mounting an IC chip and said multilayered printed circuit board are disposed at and fixed to such respective positions as to be able to transmit optical signal between the optical element of said substrate for mounting an IC chip and the optical waveguide of said multilayered printed circuit board, and

further, a resin composition for sealing is caused to flow between said substrate for mounting an IC chip and said multilayered printed circuit board and then a curing treatment is conducted, thereby forming a sealing resin layer.

[Detail Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a device for optical communication.

[0002]

Recently, attention has been focused on optical fibers mainly in communication fields. Particularly in the IT (Information Technology) field, a communication technique which employs the optical fibers is necessary to provide a high speed Internet network.

The optical fiber has features of (1) low loss, (2) high band, (3) small diameter and light weight, (4) non-induction, (5) resource saving, and the like. A communication system which employs the optical fibers having these features can considerably decrease the number of relays as compared with a communication system which employs conventional metallic cables, can be easily constructed and maintained, and can improve its economical efficiency and reliability.

[0003]

Further, since the optical fiber can transmit not only light having a single wavelength but also light having a number of different wavelengths simultaneously, i.e., only one optical

fiber can provide multiple transmission of light having a number of different wavelengths, it is possible to realize a large capacity of a transmission line capable of dealing with diversified purposes and deal with picture service and the like.

[0004]

Therefore, in the field of the network communication such as the Internet, it is proposed that the use of optical transmission using optical fibers not only for the communication of a basic network but also the communication between the basic network and terminal device (a personal computer, a mobile, a game machine or the like) and the communication between the terminal devices.

[0005]

When the optical communication is used for the communication between the basic network and the terminal device, an IC which processes information (signals) in the terminal device operates at an electric signal; therefore, the terminal device is required to include a unit that converts optical signal into an electric signal or vice versa such as an optical-to-electric converter or an electric-to-optical converter (which device will also be referred to as "optical/electric converter", hereinafter). For this reason, the conventional terminal device has mounted thereon separately, a package substrate on which an IC chip is mounted, and optical components such as a light receiving element and a light emitting element which process optical signal, and electric wirings and the optical waveguide are connected to these elements, thereby performing signal transmission and signal processing.

[0006]

[Problems to be solved by the Invention]

In such a conventional terminal device, the package substrate having an IC chip mounted thereon and optical components are separately mounted. Therefore, the size of the device itself becomes large, making it difficult to make the terminal device small in size.

Furthermore, in the conventional terminal device, since the distance between the IC mounting package substrate and the optical component is large, an electric wiring length is large and signal error or the like due to cross-talk noise or the like tend to occur during the transmission of a signal.

[0007]

Further, in the conventional device for optical communication, the area between an optical waveguide and an optical element such as a light receiving element or a light emitting element is normally a cavity. When dust, foreign matters and the like floating in the air enters into this part, the optical signal transmission is often hampered by the foreign matters and the like, thereby often increasing the connection loss between the optical components.

[0008]

[Means for Solving the Problems]

Therefore, as a result of dedicated study, the present inventors found that by mounting various types of optical components on the substrate for mounting an IC chip, it is possible to realize optical communication excellent in connection reliability and contribute to making the terminal device small in size. In addition, the present inventors found that by disposing the substrate for mounting an IC chip and the multilayered printed circuit board to be opposed to each other and forming a sealing resin layer between them, it is possible to prevent the foreign matters and the like floating in the air from entering between the respective optical components and moderate the stress generated between the substrate for mounting an IC chip and the multilayered printed circuit board, thereby ensuring a device for optical communication excellent in reliability, and completed a device for optical communication according to the present invention having the structure described below.

[0009]

That is, a device for optical communication according to

the present invention is a device for optical communication comprising: a substrate for mounting an IC chip on which at least an optical element is mounted; and a multilayered printed circuit board on which at least an optical waveguide is formed, the device for optical communication being constituted to be able to transmit optical signal between the optical waveguide and the optical element, wherein a sealing resin layer is formed between the substrate for mounting an IC chip and the multilayered printed circuit board.

[0010]

In the device for optical communication according to the present invention, it is desirable that the sealing resin layer has a transmissivity of 70 % or more for communication wavelength light.

It is also desirable that the sealing resin layer contains particles.

In the device for optical communication according to the present invention, it is desirable that the optical element is a light receiving element and/or a light emitting element.

[0011]

Further, a manufacturing method of a device for optical communication according to the present invention is a manufacturing method of a device for optical communication, wherein after separately manufacturing a substrate for mounting an IC chip on which at least an optical element is mounted, and a multilayered printed circuit board on which at least an optical waveguide is formed, the substrate for mounting an IC chip and the multilayered printed circuit board are disposed at and fixed to such respective positions as to be able to transmit optical signal between the optical element of the substrate for mounting an IC chip and the optical waveguide of the multilayered printed circuit board, and further, a resin composition for sealing is caused to flow between the substrate for mounting an IC chip and the multilayered printed circuit board and then a curing treatment is conducted, thereby forming a sealing resin layer.

[0012]

[Mode for Carrying Out the Invention]

The following description will discuss the device for optical communication according to the present invention.

A device for optical communication according to the present invention is a device for optical communication comprising: a substrate for mounting an IC chip on which at least an optical element is mounted; and a multilayered printed circuit board on which at least an optical waveguide is formed, the device for optical communication being constituted to be able to transmit optical signal between the optical waveguide and the optical element, wherein a sealing resin layer is formed between the substrate for mounting an IC chip and the multilayered printed circuit board.

[0013]

Since the device for optical communication according to the present invention comprises the substrate for mounting an IC chip on which the optical elements are mounted at predetermined positions, respectively, and the multilayered printed circuit board on which the optical waveguides are formed at predetermined positions, respectively, the connection loss between the mounted optical components is low and excellent connection reliability is ensured for the device for optical communication.

Further, in the device for optical communication, since optical components and electronic components necessary for optical communication can be provided integrally, it is possible to contribute to making a terminal device for optical communication small in size.

[0014]

In addition, since the sealing resin layer is formed between the substrate for mounting an IC chip and the multilayered printed circuit board, dust, foreign matters and the like floating in the air do not enter between the optical element and the optical waveguide. It is therefore possible to prevent the transmission of optical signal from being hampered by the

dust, the foreign matters and the like.

[0015]

Furthermore, the sealing resin layer can serve to moderate the stress derived from the difference in thermal expansion coefficient between the substrate for mounting an IC chip and the multilayered printed circuit board. Therefore, it is possible, for example, to prevent fracture and the like in the vicinity of solder bumps connecting the substrate for mounting an IC chip to the multilayered printed circuit board. Besides, by forming the sealing resin layer, the positional deviation between the optical elements and the optical waveguides is less likely to occur and thus, the transmission of optical signal between the optical elements and the optical waveguides is not hampered.

Therefore, the device for optical communication according to the present invention is excellent in reliability in these respects.

[0016]

Moreover, in the device for optical communication according to the present invention, it is desirable that the substrate for mounting an IC chip and the multilayered printed circuit board are electrically connected to each other through solder bumps. This is because the self-alignment function of solders enables to further surely dispose both at predetermined positions.

The self-alignment function means a function that a solder is to be present near the center of an opening for forming a solder bump in a more stable form due to the mobility of the solder itself at the time of the reflow treatment. It is considered that this function is generated because surface tension strongly acts so that the solder wants to be spherical when the solder adheres to metal.

In the case of utilizing this self-alignment function and even when the positional deviation occurs between the multilayered printed circuit board and the substrate for mounting

an IC chip before reflow at the time of connecting the substrate for mounting an IC chip onto the multilayered printed circuit board through the solder bumps, the substrate for mounting an IC chip moves during the reflow and can be attached to an accurate position on the multilayered printed circuit board.

Therefore, it is possible to manufacture a device for optical communication excellent in connection reliability by connecting the substrate for mounting an IC chip onto the multilayered printed circuit board through the solder bumps as long as such optical elements as a light receiving element, a light emitting element and optical waveguides are attached to respective positions accurately.

[0017]

The device for optical communication according to the present invention will now be described with reference to the drawings.

Fig. 1 is a cross-sectional view schematically showing one embodiment of the device for optical communication according to the present invention. It is noted that Fig. 1 shows the device for optical communication in a state where an IC chip is mounted.

[0018]

As shown in Fig. 1, the device for optical communication 150 comprises a substrate for mounting an IC chip 120 on which an IC chip 140 is mounted and a multilayered printed circuit board 100, with the substrate for mounting an IC chip 120 electrically connected to the multilayered printed circuit board 100 through solder connection parts 137.

A sealing resin layer 160 is formed between the substrate for mounting an IC chip 120 and the multilayered printed circuit board 100.

[0019]

The substrate for mounting an IC chip 120 is constituted such that conductor circuits 124 and interlaminar insulating layers 122 are serially built up on both faces of a substrate

121 in an alternate fashion and in repetition and that the conductor circuits across the substrate 121 and those across the interlaminar insulating layers 122 are electrically connected to one another by a plated-through hole 129 and via-holes 127, respectively.

A solder resist layer 134 comprising solder bumps for mounting the IC chip is formed on one of the outermost layers of the substrate for mounting an IC chip 120, whereas wire-bonding type light receiving element 138 and light emitting element 139 are contained in and fixed to a part of the other outermost layer (a solder resist layer opposed to the multilayered printed circuit board 100) of the substrate for mounting an IC chip 120 and electrically connected to a conductor layer 142 formed on the substrate for mounting an IC chip by wires 146, respectively. It is noted that the light receiving element 138 and the light emitting element 139 are fixed by die-bonding resin (not shown).

Further, the surrounding of each of the light receiving element 138 and the light emitting element 139 contained in the solder resist layer 134 is sealed with resin 147.

[0020]

The multilayered printed circuit board 100 is constituted such that conductor circuits 104 and interlaminar insulating layers 102 are serially built up on both faces of a substrate 101 in an alternate fashion and in repetition and that the conductor circuits across the substrate 101 and those across the interlaminar insulating layers 102 are electrically connected to one another by a plated-through hole 109 and via-holes 107, respectively.

Further, openings for optical paths 111 each having a resin layer for an optical path 108 formed therein and a solder resist layer 114 comprising solder bumps are formed on the outermost layer of the multilayered printed circuit board 100 on the side opposed to the substrate for mounting an IC chip 120, and optical waveguides 118 (118a, 118b) comprising optical path conversion mirrors 119 (119a, 119b) are formed immediately under the

openings for optical paths 111 (111a, 111b), respectively.

[0021]

In the device for optical communication 150 having the above-mentioned configuration, optical signal transmitted from the outside through an optical fiber or the like (not shown) is introduced into the optical waveguide 118a, transmitted to the light receiving element 138 (light receiving part 138a) through the optical path conversion mirror 119a, the opening for an optical path 111a and the sealing resin layer 160, and converted into an electric signal by the light receiving element 138, and the resultant electric signal is transmitted to the IC chip 140 through the conductor layer 142, the conductor circuits 124, the via-holes 127, the plated-through hole 129 and solder connection parts 143.

[0022]

Further, the electric signal transmitted from the IC chip 140 is transmitted to the light emitting element 139 through solder connection parts 143, the conductor circuits 124, the via-holes 127, the plated-through hole 129 and the conductor layer 142 and converted into optical signal by the light emitting element 139, and the resultant optical signal is introduced into the optical waveguide 118b from the light emitting element 139 (light emitting part 139a) through the sealing resin layer 160, the opening for an optical path 111b and the optical path conversion mirror 119b and transmitted to the outside through the optical fiber or the like (not shown) as optical signal.

[0023]

In such a device for optical communication according to the present invention, since the sealing resin layer is formed between the substrate for mounting an IC chip and the multilayered printed circuit board, dust, foreign matters and the like floating in the air do not enter between the optical element and the optical waveguide and the transmission of optical signal is not hampered by these dust, foreign matters and the like.

[0024]

Further, in the device for optical communication, optical/electric signal conversion is performed in the substrate for mounting an IC chip, i.e., at a position near the IC chip. Therefore, an electric signal transmission distance is short and it is possible to satisfy higher rate communication.

Furthermore, the electric signal transmitted from the IC chip is not only converted into optical signal, and then transmitted to the outside through the optical fiber as mentioned above but also the electric signal is transmitted to the multilayered printed circuit board through the solder bumps and transmitted to an electronic component such as the other IC chip mounted on the multilayered printed circuit board through the conductor circuits (including the via-holes and plated-through hole) of the multilayered printed circuit board.

[0025]

In addition, the embodiment of the device for optical communication according to the present invention is not limited to that shown in Fig. 1 but may be, for example, that shown in Figs. 2 or 3.

Fig. 2 is a cross-sectional view schematically showing another example of the device for optical communication according to the present invention. Fig. 3 is a cross-sectional view schematically showing another example of the device for optical communication according to the present invention.

[0026]

The device for optical communication shown in Fig. 2 is almost equal in structure to that shown in Fig. 1 except that optical elements (a light receiving element and a light emitting element) are fixed to a substrate for mounting an IC chip.

Namely, in the device for optical communication 150 shown in Fig. 1, the optical elements are fixed by the die-bonding resin. In the device for optical communication 250 shown in Fig. 2, by contrast, the light receiving element 238 and the light emitting element 239 are fixed by solders 244, respectively. It is noted that the solders 244 serve only to fix the respective

optical elements and that the electrical connection of the optical elements is established by wires 246, respectively.

As can be seen, the device for optical communication 250 shown in Fig. 2 differs from the device for optical communication 150 shown in Fig. 1 only in the manner of fixing the optical elements to the substrate for mounting an IC chip and the other structure of the device for optical communication 250 is equal to that of the device for optical communication 150.

[0027]

The device for optical communication shown in Fig. 3 is almost equal in structure to that shown in Fig. 1 except for the manner of mounting the optical elements (light receiving element and light emitting element).

Namely, in the device for optical communication 150 shown in Fig. 1, wire-bonding type optical elements are employed as the optical elements and the optical elements are fixed by the die-bonding resin. In the device for optical communication 350 shown in Fig. 3, by contrast, flip-chip type optical elements are employed as the light receiving element 338 and the light emitting element 339, respectively, and the light receiving element 338 and the light emitting element 339 are fixed and electrically connected by the solders 344, respectively.

Further, in the device for optical communication 350, the clearances between the bottom faces of the light receiving element 338 and the light emitting element 339 (the faces thereof opposite to the faces on which the light receiving part and the light emitting part are provided) and the solder resist layer 334 are also sealed with resin.

In this way, the device for optical communication 350 shown in Fig. 3 differs from the device for optical communication 150 shown in Fig. 1 only in the manner of mounting the optical elements and the other structure thereof is equal to that of the device for optical communication 150.

[0028]

Moreover, the device for optical communication according

to the present invention may be constituted as shown in Figs. 14 and 15. Fig. 14 is a cross-sectional view schematically showing another example of the device for optical communication according to the present invention, and Fig. 15 is a cross-sectional view schematically showing another example of the device for optical communication according to the present invention.

[0029]

The device for optical communication shown in Fig. 14 differs from that shown in Fig. 1 in the positions at which optical elements (a light receiving element and a light emitting element) are mounted and in that optical paths for transmitting optical signal for transmitting optical signal between the optical elements and optical waveguides are formed.

That is, in the device for optical communication 150 shown in Fig. 1, the optical elements are mounted on the face of the substrate for mounting an IC chip 120 on the side opposed to the multilayered printed circuit board 100. In the device for optical communication 450 shown in Fig. 14, the light receiving element 438 and the light emitting element 439 are mounted on the face of a substrate for mounting an IC chip 420 on the opposite side to that opposed to a multilayered printed circuit board 400 across a substrate. It is noted that the light receiving element 438 and the light emitting element 439 are mounted on the substrate for mounting an IC chip through solders.

[0030]

Further, the optical paths for transmitting optical signal 441 for transmitting optical signal between the light receiving element 438 and light emitting element 439 and the optical waveguides 418, respectively, are formed in the substrate for mounting an IC chip 420. A resin layer for an optical path 2442 is formed in each of the optical paths for transmitting optical signal 441 and a conductor layer 445 is formed on the wall faces thereof.

Moreover, the lower faces of the light receiving element

438 and the light emitting element 439 are sealed from a solder resist layer 434 by the resin 447.

The device for optical communication 450 having the above-mentioned configuration can transmit optical signal between the optical elements (light receiving element 438 and light emitting element 439) and the optical waveguides 118 through the optical paths for transmitting optical signal 441.

As can be seen, the device for optical communication 450 shown in Fig. 14 differs from the device for optical communication 150 shown in Fig. 1 only in the optical element mounting positions and in that the optical paths for transmitting optical signal are formed, and the other structure thereof is equal to that of the device for optical communication 150.

[0031]

The device for optical communication shown in Fig. 15 differs from the device for optical communication shown in Fig. 3 in the optical waveguide formation positions and in that optical paths for transmitting optical signal penetrating a substrate, interlaminar insulating layers and a solder resist layer on one side are formed in a multilayered printed circuit board.

That is, in the multilayered printed circuit board 300 that constitutes the device for optical communication 350 shown in Fig. 3, the optical waveguides 318 are formed on the outermost interlaminar insulating layer on the side opposed to the substrate for mounting an IC chip 320. In the multilayered printed circuit board 250 shown in Fig. 15, by contrast, optical waveguides 518 are formed on the outermost interlaminar insulating layer on the opposite side to the side opposed to the substrate for mounting an IC chip 520 across a substrate.

[0032]

Further, the optical paths for transmitting optical signal 551 penetrating the substrate 501, the interlaminar insulating layers 502 and the solder resist layer 514 on the side opposed to the substrate for mounting an IC chip 520 are formed in the multilayered printed circuit board 500. It is noted that a resin

layer for an optical path 552 is formed in each of the optical paths for transmitting optical signal 551 and that a conductor layer 555 is formed on the wall faces thereof.

The device for optical communication 550 having the above-mentioned configuration can transmit optical signal through the optical paths for transmitting optical signal 551 formed in the multilayered printed circuit board 550.

As can be seen, the device for optical communication 550 shown in Fig. 15 differs from the device for optical communication 350 shown in Fig. 3 only in the optical waveguide formation positions and in that the optical paths for transmitting optical signal are formed, and the other structure thereof is equal to that of the device for optical communication 350.

[0033]

In this way, the optical waveguide formation positions of the device for optical communication according to the present invention may be on the outermost interlaminar insulating layer on the side of the multilayered printed circuit board opposed to the substrate for mounting an IC chip as seen in the multilayered printed circuit board shown in Fig. 1 or the like, or may be on the outermost interlaminar insulating layer on the opposite side to the side opposed to the substrate for mounting an IC chip across the substrate as seen in the multilayered printed circuit board shown in Fig. 15. Besides, the optical waveguide formation positions are not limited to these positions but may be between the interlaminar insulating layers or between the substrate and the interlaminar insulating layer.

[0034]

Next, the constituent members and the like of the device for optical communication according to the present invention will be described.

As mentioned above, the device for optical communication according to the present invention has the sealing resin layer formed between the substrate for mounting an IC chip and the multilayered printed circuit board.

[0035]

The sealing resin layer is not limited to a specific one as long as the resin layer is less absorbed in a communication wavelength band. Examples of a material for the sealing resin layer include thermosetting resin, thermoplastic resin, photosensitive resin, resin obtained by photosensitizing a part of thermosetting resin, UV ray cured type resin and the like. Among them, it is desirable to use the thermosetting resin. This is because it is possible to ensure curing the resin when it is the thermosetting resin.

Specifically, examples of the material therefor include acrylic resin such as PMMA (polymethyl methacrylate), PMMA deuteride and PMMA deuteride fluoride; polyimide resin such as polyimide fluoride; epoxy resin; UV cured epoxy resin; silicone resin such as silicone resin deuteride; polymer produced from benzocyclobutene and the like.

[0036]

It is also desirable that the sealing resin layer has a transmissivity of not less than 70 % for communication wavelength light.

When the transmissivity for the communication wavelength light is less than 70 %, optical signal loss is large, which often causes the deterioration of the reliability of the device for optical communication. It is more desirable that the transmissivity is 90 % or more.

When the sealing resin layer comprises only the resin composition mentioned above, in particular, the transmissivity thereof is desirably 90 % or more. As will be described later, when particles are contained in the sealing resin layer, it is desirable that the transmissivity of the sealing resin layer is 70 % or more.

[0037]

In the present specification, the transmissivity for communication wavelength light means transmissivity for communication wavelength light per 1 mm-length. Specifically,

when light having an intensity I_1 is incident on the sealing resin layer and emitted from the sealing resin layer after passing through the sealing resin layer by 1 mm, the emitting light has an intensity I_2. The transmissivity for the light is calculated by the following expression (1).

[0038]

$$\text{Transmissivity (\%)} = (I_2/I_1) \times 100 \ \ldots \ (1)$$

[0039]

It is noted that the above-mentioned transmissivity is transmissivity measured at 25 to 30°C.

[0040]

Furthermore, it is desirable that the sealing resin layer contains particles such as resin particles, inorganic particles or metal particles.

By incorporating the particles therein, it is possible to match the thermal expansion coefficient of the substrate for mounting an IC chip to that of the multilayered printed circuit board and make it more difficult to cause cracks or the like due to the difference in thermal expansion coefficient to occur.

[0041]

In the device for optical communication according to the present invention which comprises the substrate for mounting an IC chip and the multilayered printed circuit board, the thermal expansion coefficients of the constituent members thereof (in a z-axis direction) are, for example, as follows: the thermal expansion coefficient of the substrate is about 5.0×10^{-6} to 6.0×10^{-6} (/°C), that of the interlaminar insulating layers is about 6.0×10^{-6} to 8.0×10^{-6} (/°C), that of the particles is about 0.1×10^{-6} to 1.0×10^{-6} (/°C), that of the sealing resin layer is about 0.1 which particles are mixed is about 3.0×10^{-6} to 4.0×10^{-6} (/°C), those of the IC chip and the optical elements made of silicon, germanium or the like are about 0.5×10^{-6} to 1.5×10^{-6} (/°C) and that of the conductor circuits is about 1.0×10^{-6} to 2.0×10^{-6} (/°C). It is noted that the thermal expansion coefficients $\times 10^{-6}$ to 100×10^{-6} (/°C), that of the sealing resin

layer into are measured at 20°C.

As can be seen, when particles are mixed in the sealing resin layer, the difference in thermal expansion coefficient between the sealing resin layer and the other constituent members that constitute the device for optical communication is decreased. Therefore, a stress is moderated.

Further, when particles are mixed in the sealing resin layer, the positional deviation of the optical elements and the optical waveguides is less likely to be caused.

[0042]

Moreover, when the particles are mixed in the sealing resin layer, it is desirable that the resin component of the sealing resin layer is almost equal in refractive index to the particles. Therefore, when the particles are mixed in the sealing resin layer, it is desirable to mix two or more kinds of particles having different refractive indexes together to set the refractive index of the particles almost equal to that of the resin composition.

Specifically, when the resin component is, for example, epoxy resin having a refractive index of 1.53, it is desirable to use a mixture of silica particles having a refractive index of 1.54 and titania particles having a refractive index of 1.52.

Examples of a method of mixing up the particles include a kneading method and a method of dissolving and mixing up two or more kinds of particles and, then, forming them into particle shape.

[0043]

Examples of the resin particles include those comprising thermosetting resin, thermoplastic resin, photosensitive resin, resin obtained by photosensitizing a part of thermosetting resin, a resin complex comprising thermosetting resin and thermoplastic resin, a complex comprising photosensitive resin and thermoplastic resin and the like.

[0044]

Specifically, they include, for example, thermosetting

resin such as epoxy resin, phenol resin, polyimide resin, bismaleimide resin, polyphenylene resin, polyolefin resin and fluororesin; resin obtained by reacting the thermosetting group of one of these thermosetting resins (e.g., the epoxy group of epoxy resin) with an methacrylic acid, an acrylic acid or the like to impart an acrylic group to the resin; thermoplastic resin such as phenoxy resin, polyethersulfone (PES), polysulfone (PSF), polyphenylenesulfone (PPS), polyphenylene sulfide (PPES), polyphenyl ether (PPE) and polyetherimide (PI); photosensitive resin such as acrylic resin and the like.

Further, resin particles comprising a resin complex comprising the thermosetting resin and the thermoplastic resin or a resin complex comprising the acrylated resin, the photosensitive resin and the thermoplastic resin can be used.

As the resin particles, rubber-containing resin particles can be also used.

[0045]

In addition, examples of the inorganic particles include those comprising aluminum compounds such as alumina and aluminum hydroxide; calcium compounds such as calcium carbonate and calcium hydroxide; potassium compounds such as potassium carbonate; magnesium compounds such as magnesia, dolomite and basic magnesium carbonate; silicon compounds such as silica and zeolite; titanium compounds such as titania and the like. Further, the inorganic particles comprising a material obtained by mixing silica and titania with a certain rate, dissolving and making them even may be used.

As the inorganic particles, those comprising phosphorus or phosphorus compounds can be also used.

[0046]

Examples of the metal particles include those comprising gold, silver, copper, palladium, nickel, platinum, iron, zinc, lead, aluminum, magnesium, calcium and the like.

These resin particles, inorganic particles and metal particles may be used alone or in combination of two or more

of them.

[0047]

Further, the shape of the particles is not limited to specific one and examples of the particles include a spherical shape, an elliptic shape, a friable shape, a polygonal shape and the like. Among these shapes, the spherical shape or the elliptic shape is desirable. This is because the spherical or elliptic particle has no corners, which makes it more difficult to cause cracks and the like to occur to the sealing resin layer.

Moreover, when the particles are spherical or elliptic, it is difficult to reflect light on the particles, thus lowering optical transmission loss.

[0048]

The lower limit of the particle diameter is desirably 0.01 μm, and more desirably 0.1 μm. The upper limit of the particle diameter is desirably 100 μm, and more desirably 50 μm. The upper limit is desirably shorter than the communication wavelength. This is because, when the average particle diameter of the particles is smaller than the communication wavelength, the risk of blocking the optical signals is reduced.

Moreover, two or more different kinds of particles may be mixed as long as the particle diameters thereof are in the foregoing range.

In the specification, the diameter of the particles refers to length of the longest part of the particle.

[0049]

The lower limit of the amount of the particles included in the sealing resin layer is desirably 10% by weight, and more desirably 20% by weight. The upper limit of the amount of the particles is desirably 80% by weight, and more desirably 70% by weight. When the mixing quantity of the particles is less than 10% by weight, the effect of mixing particles cannot be sometimes expected. When it exceeds 50% by weight, the transmission of optical signal is sometimes hampered.

The composition of the sealing resin layer has an influence

on reliabilities such as the optical signal transmission loss, heat resistance and bending strength. Therefore, the specific composition may be appropriately selected so that the sealing resin layer satisfies low optical signal transmission loss, excellent heat resistance and excellent cracking resistance.

[0050]

Optical elements (light receiving element, light emitting element) are mounted on the substrate for mounting an IC chip which constitutes the device for optical communication according to the present invention.

Examples of the light receiving element include a PD (photodiode), an APD (avalanche photodiode) and the like.

They may be appropriately selected based on the configuration of the substrate for mounting an IC chip, required characteristics and the like.

Examples of a material for the light receiving element include Si, Ge, InGaAs and the like.

Among them, InGaAs is desirable because of its excellent light receiving sensitivity.

[0051]

Examples of the light emitting element include an LD (semiconductor laser), a DFB-LD (distributed feedback type semiconductor laser), an LED (light emitting diode) and the like.

They may be appropriately selected based on the configuration of the substrate for mounting an IC chip, required characteristics and the like.

[0052]

Examples of a material for the light emitting element include a compound of gallium, arsenic and phosphorus (GaAsP), a compound of gallium, aluminum and arsenic (GaAlAs), a compound of gallium and arsenic (GaAs), a compound of indium, gallium and arsenic (InGaAs), a compound of indium, gallium, arsenic and phosphorus (InGaAsP) and the like.

They may be selected based on the communication wavelength. When the communication wavelength is in a 0.85 μm band, GaAlAs

can be used. When the communication wavelength is in a 1.3 μm band or a 1.55 μm band, InGaAs or InGaAsP can be used.

[0053]

It is noted that the optical elements (light receiving element and light emitting element) may be electrically connected to the substrate for mounting an IC chip by wire-bonding or flip-chip bonding at the time of mounting them on the substrate for mounting an IC chip.

Further, when the optical elements are electrically connected by wire-bonding, the optical elements may be fixed to the substrate for mounting an IC chip using die-bonding resin or solders.

[0054]

Moreover, as shown in the figures, in the device for optical communication according to the present invention, the surroundings of the optical elements mounted on the substrate for mounting an IC chip are desirably sealed with resin and the sealing resin is made of the similar material as that for the sealing resin layer. Accordingly, particles may be mixed in the resin for sealing the surroundings of the optical elements, and the transmissivity of the resin is desirably 70 % or more when particles are mixed therein and 90 % or more when the resin comprising only the resin component.

In addition, when the optical elements are electrically connected to the substrate for mounting an IC chip by flip-chip bonding,

[0055]

In addition, in the substrate for mounting an IC chip of the device for optical communication, the optical elements (light receiving element and light emitting element) are mounted on the substrate for mounting an IC chip so as to be embedded into the solder resist layer and the surroundings of the optical elements are sealed with resin. However, in the substrate for mounting an IC chip that constitutes the device for optical communication according to the present invention, the optical

elements are not always mounted on the substrate for mounting an IC chip so that the entire optical elements are embedded into the solder resist layer. Instead, the optical elements may be mounted thereon so that a part of the optical elements are embedded into the solder resist layer or mounted on the surface of the solder resist layer so that the optical elements are not at all embedded into the solder resist layer.

Even when the optical elements are mounted so that a part of the optical elements are embedded or the optical elements are not at all embedded into the solder resist layer, the surroundings of the optical elements may be sealed with resin.

[0056]

Moreover, it is desirable that solder bumps for transmitting an electric signal are formed on the substrate for mounting an IC chip. By forming the solder bumps, it is possible to transmit an electric signal between the substrate for mounting an IC chip and an external electronic component.

[0057]

Optical waveguides are formed on the multilayered printed circuit board that constitutes the device for optical communication according to the present invention.

Examples of the optical waveguide include an organic optical waveguide made of a polymer material or the like, an inorganic optical waveguide made of a quartz glass, a compound semiconductor or the like, and the like. Among them, the organic optical waveguide made of a polymer material or the like is desirable. This is because the organic optical waveguide is excellent in adhesion to the interlaminar insulating layer, easy to work with and can be obtained at low cost.

[0058]

The polymer material is not limited to a specific one as long as the polymer material is less absorbed in a communication wavelength band. Examples of the polymer material include thermosetting resin, thermoplastic resin, photosensitive resin, resin obtained by photosensitizing a part of thermosetting resin

and the like, a complex of thermosetting resin and thermoplastic resin, a complex of photosensitive resin and thermoplastic resin and the like.

[0059]

Specific examples of the polymer material include acrylic resin such as PMMA (polymethyl methacrylate), PMMA deuteride and PMMA deuteride fluoride; polyimide resin such as polyimide fluoride; epoxy resin; UV cured epoxy resin; polyolefin resin; silicone resin such as silicone resin deuteride; siloxane resin; polymer produced from benzocyclobutene and the like.

[0060]

The optical waveguide may include, for example, particles such as resin particles, inorganic particles and the metal particles, in addition to the resin components.

Specific examples of the particles include the same as those contained in the sealing resin layer.

[0061]

Further, the shape of the particles is not limited to a specific one but the particles may be spherical, elliptic, friable, polygonal or the like. Among these shapes, the spherical shape or the elliptic shape is desirable. This is because the spherical or elliptic particle has no corners, which makes it more difficult to cause cracks and the like to occur to the optical waveguides.

When the particles are spherical or elliptic, light is less likely to be reflected by the particles, thus lowering optical signal loss.

[0062]

The lower limit of the particle diameter of the particles is desirably 0.01 μm, and more desirably 0.1 μm.

The upper limit of the particle diameter is desirably 100 μm, and more desirably 50 μm. The upper limit is desirably shorter than the communication wavelength. This is because, when the average particle diameter of the particles is smaller than the communication wavelength, the risk of blocking the

optical signals is reduced.

Moreover, two or more different kinds of particles may be mixed as long as the particle diameters thereof are in the foregoing range.

[0063]

The lower limit of the amount of the particles included in the optical waveguide is desirably 10% by weight, and more desirably 20% by weight. The upper limit of the amount of the particles is desirably 80% by weight, and more desirably 70% by weight. When the mixing quantity of the particles is less than 10% by weight, the effect of mixing particles cannot be sometimes expected. When it exceeds 50% by weight, the transmission of optical signal is sometimes hampered. The shape of the optical waveguide is not particularly limited, and is desirably a sheet-like shape because of its easy formation.

[0064]

In the case that the optical waveguides contain particles, it is possible to match the thermal expansion coefficients between the optical waveguides and the substrates, interlayer resin insulation layer, or the like constituting the multiplayer printed circuit board, which makes it more difficult to cause cracks, peeling or the like due to the difference in thermal expansion coefficient to occur.

[0065]

Each of the optical waveguides has desirably a thickness of 1 to 100 μm and a width of 1 to 100 μm. When the width is less than 1 μm, it is difficult to form the optical waveguide in some cases. When the width exceeds 100 μm, this hampers the degree of freedom for the design of the conductor circuits and the like that constitute the multilayered printed circuit board in some cases.

[0066]

Furthermore, the ratio of the thickness to width of each of the optical waveguides is desirably close to 1 : 1. This is because the planar shapes of the light receiving part of the

light receiving element and the light emitting part of the light emitting part are normally circular shapes. It is noted that the ratio of thickness to width is not limited to a specific one but may be normally in the range of about 1 : 2 to 2 : 1.

Moreover, when each of the optical waveguides is an optical waveguide for single-mode having a communication wavelength of 1.55 μm, the optical waveguide has a thickness and a width of more desirably 5 to 15 μm. When each of the optical waveguides is an optical waveguide for multi-mode having a communication wavelength of 0.85 μm, the thickness and the width is desirably 20 to 80 μm.

[0067]

In addition, it is desirable that an optical waveguide for light reception and an optical waveguide for light emission are formed as the optical waveguides, respectively. The optical waveguide for light reception means an optical waveguide for transmitting optical signal sent from the outside through an optical fiber or the like to the light receiving element, and the optical waveguide for light emission means an optical waveguide for transmitting optical signal sent from the light emitting element to the optical fiber or the like.

It is also desirable that the optical waveguide for light reception and the optical waveguide for light emission are made of the same material. When they are made of the same material, it is easy to match the thermal expansion coefficients and the like between them and easy to form the optical waveguides.

[0068]

It is desirable that an optical path conversion mirror is formed on each of the optical waveguides as mentioned above. By forming the optical path conversion mirror, it is possible to change the angle of the optical path to a desired angle.

The optical path conversion mirror can be formed by cutting one end of each optical waveguide.

[0069]

Furthermore, in the multilayered printed circuit board

that constitutes the device for optical communication shown in the figure, the optical waveguides are formed on the outermost interlaminar insulating layer and the solder resist layer is formed to cover this interlaminar insulating layer and the optical waveguides. However, this solder resist layer is not necessarily formed but, for example, the optical waveguides may be formed entirely on the outermost interlaminar insulating layer to serve as the solder resist layer.

[0070]

Furthermore, in the substrate for mounting an IC chip, when the optical elements are mounted on the face of the substrate for mounting an IC chip opposite to the face opposed to the multilayered printed circuit board across the substrate as shown in Fig. 14, optical paths for transmitting optical signal are formed in the substrate for mounting an IC chip. Accordingly, optical signal can be transmitted through the optical paths for transmitting optical signal.

[0071]

It is desirable that a resin layer for an optical path is formed in each of the optical paths for transmitting optical signal. The formation of such a resin layer for an optical path is suitable for the formation of the sealing resin layer and makes it more difficult for dust, foreign matters and the like to enter the optical paths for transmitting optical signal.

In addition, when the resin layer for an optical path is formed in each of the optical paths for transmitting optical signal, the strength of the substrate for mounting an IC chip becomes more excellent.

[0072]

The resin component of the resin layer for an optical path is not limited to a specific one as long as the resin component is less absorbed in a communication wavelength band. Specific examples of the resin component include the same resin as that used for the sealing resin layer.

Furthermore, particles such as resin particles, inorganic

particles and metal particles may be contained in the resin layer for an optical path besides the resin component. By incorporating these particles in the resin layer for an optical path, it is possible to match the thermal expansion coefficients of the optical paths for transmitting optical signal, the substrate, the interlaminar insulating layers, the solder resist layers and the like.

Specific examples of the particles include the same as those contained in the sealing resin layer.

[0073]

Further, the shape of the optical paths for transmitting optical signal is not limited to a specific one but they may be, for example, columnar, elliptical columnar, quadrangular columnar, polygonal columnar or the like. Among these shapes, the columnar shape is desirable. This is because it is easy to form the optical waveguides into spherical shape.

[0074]

The lower limit of the cross-sectional diameter of each of the optical paths for transmitting optical signal is desirably 100 μm. When the cross-sectional diameter is less than 100 μm, the optical path may possibly be closed and it is often difficult to form the resin layer for an optical path in the optical path for transmitting optical signal. On the other hand, the upper limit of the cross-sectional diameter thereof is desirably 500 μm. Even when the cross-sectional diameter exceeds 500 μm, the optical signal transmission characteristic does not improve so greatly and such a large cross-sectional diameter often hampers the degree of freedom for the design of conductor circuits and the like that constitute the substrate for mounting an IC chip.

The lower limit and upper limit of the cross-sectional diameter are more desirably 250 μm and 350 μm, respectively from a viewpoint that both the optical signal transmission characteristic and the degree of freedom for design are excellent and no problem occurs even when an uncured resin composition is filled into the optical paths having the cross-sectional

diameter.

The cross-sectional diameter of each of the optical paths for transmitting optical signal means the diameter of a cross section when the optical path for transmitting optical signal is cylindrical, the longer diameter of the cross section when the optical path for transmitting optical signal is elliptic, and the length of the longest portion of the cross section when the optical path for transmitting optical signal is prismatic or polygonal.

[0075]

It is also desirable that a conductor layer is formed on the wall faces of each of the optical paths for transmitting optical signal. The conductor layer may comprise one layer or two or more layers.

Examples of a material for the conductor layer include copper, nickel, chromium, titanium, noble metal and the like.

Further, the conductor layer can often serve as a plated-through hole, i.e., serve to electrically connect the conductor circuits across the substrate or the conductor circuits across the substrate and the interlaminar insulating layers.

[0076]

In addition, the material for the conductor layer may be metal having glossiness such as gold, silver, nickel, platinum, aluminum and rhodium. The conductor layer which is formed out of such metal having glossiness suitably reflects optical signal.

In addition, a covering layer or roughened layer made of tin, titanium, lead and the like may be further provided on the conductor layer. By providing the covering layer or roughened layer, it is possible to improve the adhesion of the resin layer for an optical path.

[0077]

Furthermore, when the conductor layer and the resin layer for an optical path are formed in each of the optical paths for transmitting optical signal, they may contact with the substrate or the interlaminar insulating layer through a roughened face.

When the conductor layer contacts therewith through the roughened face, the adhesion thereof to the substrate or the interlaminar insulating layer is excellent, making it more difficult to cause the peeling of the conductor layer and the like.

[0078]

The device for optical communication having the above-mentioned configuration according to the first aspect of the second group of the present invention can be manufactured by a manufacturing method of a device for optical communication according to the second aspect of the second group of the present invention to be described later, or the like.

[0079]

Next, the manufacturing method of the device for optical communication according to the present invention will be described.

In the manufacturing method of the device for optical communication according to the present invention, after separately manufacturing a substrate for mounting an IC chip on which at least an optical element is mounted, and a multilayered printed circuit board on which at least an optical waveguide is formed, the substrate for mounting an IC chip and the multilayered printed circuit board are disposed at and fixed to such respective positions as to be able to transmit optical signal between the optical element of the substrate for mounting an IC chip and the optical waveguide of the multilayered printed circuit board, and further, a resin composition for sealing is caused to flow between the substrate for mounting an IC chip and the multilayered printed circuit board and then a curing treatment is conducted, thereby forming a sealing resin layer.

[0080]

In the manufacturing method of the device for optical communication according to present invention, after disposing and fixing the substrate for mounting an IC chip and the multilayered printed circuit board at and to the respective predetermined positions, the sealing resin layer is formed

between them. Therefore, dust, foreign matters and the like floating in the air do not enter between the optical element and the optical waveguide, and it is possible to suitably manufacture the device for optical communication capable of preventing the transmission of optical signal from being hampered by the dust, the foreign matters and the like.

[0081]

Furthermore, by forming the sealing resin layer between the substrate for mounting an IC chip and the multilayered printed circuit board, the sealing resin layer can serve to moderate the stress derived from the difference in thermal expansion coefficient between the substrate for mounting an IC chip and the multilayered printed circuit board in the device for optical communication thus obtained. In addition, by forming the sealing resin layer, the positional deviation between the optical elements and the optical waveguides becomes less likely to be caused.

Therefore, in the manufacturing method of the device for optical communication according to the present invention, it is possible to suitably manufacture a device for optical communication excellent in reliability.

[0082]

In the manufacturing method of the device for optical communication according to the present invention, first, the substrate for mounting an IC chip and the multilayered printed circuit board are separately manufactured.

Accordingly, the manufacturing method of the substrate for mounting an IC chip and the manufacturing method of the multilayered printed circuit board will be described separately first, and then a method of forming the sealing resin layer will be described herein.

[0083]

First, the manufacturing method of the substrate for mounting an IC chip will be described.

(1) Using an insulating substrate as a starting material,

conductor circuits are formed on the insulating substrate.

Examples of the insulating substrate include a glass epoxy substrate, a polyester substrate, a polyimide substrate, a bismaleimide-triaging (BT) resin substrate, a thermosetting polyphenylene ether resin, a copper-clad laminated board, an RCC substrate and the like.

Alternatively, a ceramic substrate such as an aluminum nitride substrate or a silicon substrate may be used.

The conductor circuits may be formed by forming a conductor layer in a spread state on each surface of the insulating substrate by an electroless plating treatment or the like and then etching the resultant conductor layer. Alternatively, the conductor circuits may be formed by etching the copper-clad laminated board or the RCC substrate.

[0084]

When the conductor circuits with the insulating substrate interposed therebetween are connected to each other by a plated-through hole, the plated-through hole is formed by forming a through hole for a plated-through hole in the insulating substrate using a drill, a laser or the like and, then, conducting an electroless plating treatment or the like. It is desirable to fill the plated-through hole with a resin filler when the plated-through hole is formed.

[0085]

(2) Next, the surfaces of the conductor circuits are subjected to a roughening treatment, based on necessity.

Examples of the roughening treatment include a blackening (oxidizing)-reducing treatment, an etching treatment using an etchant containing a cupric complex and an organic acid salt, a Cu-Ni-P needle-like alloy plating treatment and the like.

This roughening treatment may be performed before filling the plated-through hole with the resin filler and roughened faces may be formed even on the wall faces of the plated-through hole. This is because the adhesion between the plated-through hole

and the resin filler is improved.

[0086]

(3) Either an uncured resin layer of thermosetting resin, photosensitive resin, resin obtained by acrylating a part of thermosetting resin, an uncured resin layer of a resin complex containing one of these resins and thermoplastic resin, or a resin layer of thermoplastic resin is formed on the substrate on which the conductor circuits are formed.

The uncured resin layer can be formed by applying uncured resin by a roll coater, a curtain coater or the like or by thermally bonding an uncured (half-cured) resin film.

Further, the resin layer of the thermoplastic resin can be formed by thermally bonding a resin formed body formed into film shape.

[0087]

Among these formation methods, it is desirable to use the formation method of thermally bonding the uncured (half-cured) resin film. The resin film can be thermally bonded using a vacuum laminator or the like.

Furthermore, bonding conditions are not limited to specific ones but may be appropriately selected in view of the composition of the resin film and the like. Normally, it is desirable to carry out bonding under conditions of a pressure of 0.25 to 1.0 MPa, a temperature of 40 to 70°C, degree of vacuum of 13 to 1300 Pa, a period of time of about 10 to 120 seconds.

[0088]

Examples of the thermosetting resin include epoxy resin, phenol resin, polyimide resin, polyester resin, bismaleimide resin, polyolefin resin, polyphenylene ether resin, polyphenylene resin, fluororesin and the like.

Specific examples of the epoxy resin include novolak type epoxy resins such as phenol novolak type epoxy resin and cresol novolak type epoxy resin; dicyclopentadiene-modified alicyclic epoxy resin and the like.

[0089]

Examples of the photosensitive epoxy resin include acrylic resin and the like.

Further, examples of the resin in which a part of thermosetting resin is provided with a photosensitive group include resin obtained by acrylating the thermosetting group of the thermosetting resin with a methacrylic acid or an acrylic acid and the like.

[0090]

Examples of the thermoplastic resin include phenoxy resin, polyethersulfone (PES), polysulfone (PSF), polyphenylenesulfone (PPS), polyphenylene sulfide (PPES), polyphenyl ether (PPE), polyetherimide (PI) and the like.

[0091]

Further, the resin complex is not limited to a specific one as long as the resin complex comprises thermosetting resin or photosensitive resin (including resin in which a part of thermosetting resin is provided with a photosensitive group), and thermoplastic resin. Specific examples of the combination of the thermosetting resin and the thermoplastic resin include phenol resin/polyethersulfone, polyimide resin/polysulfone, epoxy resin/polyethersulfone, epoxy resin/phenoxy resin and the like. In addition, specific examples of the combination of the photosensitive resin and the thermoplastic resin include acrylic resin/phenoxy resin, epoxy resin obtained by acrylating a part of the epoxy group thereof and polyethersulfone and the like.

[0092]

Furthermore, the mixing ratio of the thermosetting resin or photosensitive resin and the thermoplastic resin of the resin complex is desirably thermosetting resin or photosensitive resin/thermoplastic resin = 95/5 to 50/50. With this ratio, it is possible to ensure high toughness without deteriorating heat resistance.

[0093]

In addition, the resin layer may be composed of two or more different resin layers.

Specifically, the resin layer be composed of upper and lower layers. The lower layer of the resin layer is formed of, for example, a resin complex having a mixing ratio of thermosetting resin or photosensitive resin/thermoplastic resin = 50/50 and the upper layer thereof is formed of, for example, a resin complex having a mixing ratio of thermosetting resin or photosensitive resin/thermoplastic resin = 90/10.

With this configuration adopted, it is possible to ensure excellent adhesion between the resin layer and the insulating substrate and to ensure facilitating the formation of openings for via-holes and the like in later steps.

[0094]

Further, the resin layer may be formed using a resin composition for forming a roughened face.

Examples of the resin composition for forming a roughened face include a composition in which a substance soluble in a roughening solution containing at least one kind selected from an acid, an alkali and an oxidizing agent is dispersed in an uncured heat resistant resin matrix hardly soluble in a roughening solution containing at least one kind selected from an acid, an alkali and an oxidizing agent, and the like.

As for the terms "hardly soluble" and "soluble", substances which have a relatively high dissolution speed are called "soluble" substances and those which have a relatively slow dissolution speed are called "hardly soluble" substances for the sake of convenience when they are immersed in the same roughening solution for the same period of time.

[0095]

The heat resistant resin matrix is desirably capable of keeping the shape of a roughened face at the time of forming the roughened face on the interlaminar insulating layer using the roughening solution. Examples of the heat resistant resin matrix include thermosetting resin, thermoplastic resin, complexes thereof and the like. In addition, photosensitive resin may be used. The photosensitive resin may be used as well.

When using the photosensitive resin, openings for via-holes can be formed in the interlaminar insulating layer using exposure and development treatments.

[0096]

Examples of the thermosetting resin include epoxy resin, phenol resin, polyimide resin, polyolefin resin, fluororesin and the like. Further, when the thermosetting resin is photosensitized, the thermosetting group of the resin is (meth)acrylated using a methacrylic acid, an acrylic acid or the like.

[0097]

Examples of the epoxy resin include cresol novolak type epoxy resin, bisphenol A type epoxy resin, bisphenol F type epoxy resin, phenol novolak type epoxy resin, alkyl phenol novolak type epoxy resin, bi-phenol F type epoxy resin, naphthalene type epoxy resin, dicyclopentadiene type epoxy resin, epoxylated compounds of condensates of phenols and aromatic aldehydes containing a phenolic hydroxyl group, triglycidyl isocyanurate, alicyclic epoxy resin and the like. They may be used alone or in combination of two or more of them. Accordingly, excellent heat resistance can be ensured.

[0098]

Examples of the thermoplastic resin include phenoxy resin, polyethersulfone, polysulfone, polyphenylenesulfone, polyphenylene sulfide, polyphenyl ether, polyetherimide and the like. They may be used alone or in combination of two or more of them.

[0099]

The substance soluble to the roughening solution containing at least one kind of compounds selected from the acid, alkali and oxidizing agent is desirably at least one kind selected from inorganic particles, resin particles and metal particles.

[0100]

Examples of the inorganic particles include aluminum compounds such as alumina and aluminum hydroxide, calcium

compounds such as calcium carbonate and calcium hydroxide, potassium compounds such as potassium carbonate, magnesium compounds such as magnesia, dolomite, basic magnesium carbonate, and tarc, silicon compounds such as silica and zeolite, and the like. They may be used alone or in combination of two or more of them.

[0101]

Examples of the resin particles include thermosetting resin, thermoplastic resin and the like, and those which have a higher dissolution speed than that of the heat resistant resin matrix at the time of being immersed in a roughening solution containing at least one kind of compounds selected from an acid, an alkali, and an oxidizing agent can be used without any specific limitation. Specifically, examples thereof include amino resin (melamine resin, urea resin, guanamine resin and the like), epoxy resin, phenol resin, phenoxy resin, polyimide resin, polyphenylene resin, polyolefin resin, fluororesin, bismaleimide-triaging resin and the like. They may be used alone or in combination of two or more of them.

The resin particles are required to be previously subjected to a curing treatment. When the resin particles are not cured, they are dissolved in a solvent for dissolving the resin matrix.

As the resin particles, rubber particles, liquid-phase resin, liquid-phase rubber or the like may be used.

[0102]

Examples of the metal particles include gold, silver, copper, tin, zinc, stainless steel, aluminum, nickel, iron, lead and the like. They may be used alone or in combination of two or more kinds of them.

Further, the surface layer of the metal particles may be covered with resin in order to ensure the insulating property.

[0103]

When two or more kinds of the soluble substances are mixed together, a mixture combination of the two soluble substances is desirably a combination of resin particles and inorganic

particles. The reason is as follows. Since both the resin particles and the inorganic particles are low in conductivity, it is possible to ensure the insulating property of the interlaminar insulating layer, facilitate adjusting thermal expansion relative to the hardly soluble resin, prevent the occurrence of cracks to the interlaminar insulating layer of the resin composition for forming roughened surface, and prevent the occurrence of peeling between the interlaminar insulating layer and the conductor circuit.

[0104]

Examples of the acid used as the roughening solution include a phosphoric acid, a hydrochloric acid, a sulfuric acid, a nitric acid, organic acids such as a formic acid and an acetic acid and the like. Among them, it is desirable to use an organic acid for the roughening solution. This is because the organic acid makes it difficult to corrode the metallic conductor layer exposed from the via-holes when a roughening treatment is conducted.

As the oxidizing agent, an aqueous solution containing a chromic acid, a chromic sulfide, an alkaline permanganic acid (e.g., potassium permanganate) or the like is desirable.

As the alkali, an aqueous solution containing sodium hydroxide, potassium hydroxide or the like is desirable.

[0105]

The average particle diameter of the soluble substances is desirably 10 μm or less.

Alternatively, coarse particles having a relatively large average particle diameter of 2 μm or less and fine particles having a relatively small average particle diameter may be combined. For example, a soluble substance having an average particle diameter of 0.1 to 0.5 μm and a soluble substance having an average particle diameter of 1 to 2 μm may be combined.

[0106]

By thus combining the coarse particles having a relatively large average particle diameter with the fine particles having

a relatively small average particle diameter, it is possible to eliminate the solution residue of the electroless deposition film, decrease the quantity of palladium catalyst under the plating resist and form shallow, complicated roughened faces.

Furthermore, by forming the complicated roughened faces, it is possible to maintain a practical peel strength even when the roughened faces have small irregularities.

Desirably, the average particle diameter of the coarse particles exceeds 0.8 μm and is less than 2.0 μm, and that of the fine particles is 0.1 to 0.8 μm.

[0107]

(4) Next, in the case of forming an interlaminar insulating layer using the thermosetting resin or resin complex as a material therefor, a curing treatment is conducted to an uncured resin layer and openings for via-holes are formed to obtain the interlaminar insulating layer. In this step, a through hole for a plated-through hole may be formed, based on necessity.

It is desirable that the openings for via-holes are formed by a laser treatment. In addition, when photosensitive resin is used as a material for the interlaminar insulating layer, the openings may be formed by exposure and development treatments.

[0108]

When the interlaminar insulating layer is formed using thermoplastic resin as a material therefor, openings for via-holes are formed in a resin layer of thermoplastic resin to provide the interlaminar insulating layer. In this case, the openings can be formed by conducting a laser treatment.

When a through hole is to be formed in this step, it may be formed by drilling, a laser treatment or the like.

[0109]

Examples of a laser used for the laser treatment include a carbonic acid gas laser, a UV laser, an excimer laser and the like. Among them, the excimer laser or the carbonic acid gas laser having a short pulse is desirable.

[0110]

Further, among various excimer lasers, a hologram type excimer laser is desirable. A hologram type excimer laser is a laser which applies a laser beam onto a target through a hologram, a condensing lens, a laser mask, a transfer lens or the like. By using this method, it is possible to efficiently form a large number of openings in the resin film layer by the application of the laser beam at one time.

[0111]

When the carbonic acid gas laser is used, the pulse interval of the laser is desirably 10^{-4} to 10^{-8} seconds. In addition, a period of time for applying a laser beam to form openings is desirably 10 to 500 microseconds.

In addition, by applying a laser beam through an optical system lens and a mask, it is possible to form a large number of openings for via-holes at one time. This is because a laser beam with the same intensity and the same application angle can be applied to a plurality of parts by letting the laser beam pass through the optical system lens and the mask.

After thus forming the openings for via-holes, based on necessity, a desmear treatment may be conducted.

[0112]

(5) Next, conductor circuits are formed on the surface of the interlaminar insulating layer including the inner walls of the openings for via-holes.

When the conductor circuit is to be formed, a thin film conductor layer is formed first on the surface of interlaminar insulating layer.

The thin film conductor layer can be formed by electroless plating, sputtering or the like.

[0113]

Examples of a material for the thin film conductor layer include copper, nickel, tin, zinc, cobalt, thallium, lead and the like.

Among these materials, the thin film conductor layer of

copper or copper and nickel is desirable because of its or their excellent electric characteristics, economical advantage and the like.

Further, when the thin film conductor layer is formed by electroless plating, the thickness of the thin film conductor layer is desirably 0.3 to 2.0 μm, and more desirably 0.6 to 1.2 μm. Further, when the thin film conductor layer is formed by sputtering, the thickness is desirably 0.1 to 1.0 μm.

[0114]

Alternatively, a roughened face may be formed on the surface of the interlaminar insulating layer before the thin film conductor layer is formed. When the roughened face is formed, it is possible to improve the adhesion between the interlaminar insulating layer and the thin film conductor layer. When the interlaminar insulating layer is formed using the resin composition for forming a roughened face, in particular, it is desirable to form the roughened face using an acid, an oxidizing agent or the like.

[0115]

Furthermore, when the through hole is formed in the step (4), the thin film conductor layer may be formed even on the wall face of the through hole at the time of forming the thin film conductor layer on the interlaminar insulating layer.

[0116]

(6) Next, a plating resist is formed on the substrate on the surface of which the thin film conductor layer is formed.

The plating resist can be formed by: bonding a photosensitive dry film, closely disposing a photomask made of a glass substrate or the like drawing a plating resist pattern; and conducting exposure and development treatments.

[0117]

(7) Thereafter, electroplating is conducted using the thin film conductor layer as a plating lead to form an electroplating layer in non plating resist formed areas. The electroplating is desirably copper plating.

Further, the thickness of the electroplating layer is desirably 5 to 20 μm.

[0118]

Thereafter, the plating resist and the electroless deposition film and the thin film conductor layer under the plating resist are removed, whereby conductor circuits (including via-holes) can be formed.

The removal of the plating resist may be carried out using, for example, an alkali aqueous solution or the like, and the removal of the thin film conductor layer may be carried out using an etchant containing a solution mixture of a sulfuric acid and peroxide, sodium persulfate, ammonium persulfate, ferric chloride, cupric chloride or the like.

Further, after forming the conductor circuits, a catalyst on the interlaminar insulating layer may be removed by an acid or an oxidizing agent, based on necessity. When the catalyst is removed, it is possible to prevent the deterioration of electric characteristic.

[0119]

While the formation method of the conductor circuit described herein is based on an additive method, the formation method of the conductor circuit in the manufacturing method according to the present invention is not limited to that based on the additive method but may be based on a subtractive method.

A method of forming the conductor circuits based on the subtractive method will be briefly described hereinafter.

[0120]

Namely, after forming an interlaminar insulating layer having openings for via-holes, a thin film conductor layer is formed on the surface of the interlaminar insulating layer including the wall faces of the openings for via-holes similarly to the step (5).

[0121]

Next, an electroplated layer or the like is formed on the entire face of the thin film conductor layer, thereby increasing

the thickness of the conductor layer. It is noted that the formation of the electroplated layer or the like may be carried out based on necessity.

Next, an etching resist is formed on the conductor layer.

The etching resist is formed by bonding a photosensitive dry film, closely disposing a photomask on the photosensitive dry film and conducting exposure and development treatment and the like.

[0122]

Furthermore, the conductor layer under non etching resist formed areas is removed by an etching treatment and the etching resist is then peeled off, whereby independent conductor circuits (including via-holes) are formed on the interlaminar insulating layer.

The etching treatment can be carried out using an etchant containing a solution mixture of a sulfuric acid and peroxide, sodium persulfate, ammonium persulfate, ferric chloride, cupric chloride or the like and the peeling of the etching resist can be carried out using an aqueous alkaline solution.

Even by using such a method, it is possible to form the conductor circuits on the interlaminar insulating layer.

[0123]

Whether to select the additive method or the subtractive method of the formation method of the conductor circuit may be appropriately determined based on the width and distance of the conductor circuits, the number of connection terminals, the pitch and the like for the IC chip and the optical elements to be mounted on the substrate and other various electronic components.

[0124]

Moreover, when the plated-through hole is formed in the steps (4) and (5), a resin filler may be filled into the plated-through hole.

Further, when the resin filler is filled into the plated-through hole, a cover plated layer may be formed to cover the surface layer part of the resin filled layer by performing

electroless plating based on necessity.

[0125]

(8) When the cover plated layer is formed, a roughening treatment is conducted to the surface of the cover plated layer if necessary and the steps (3) to (7) are repeatedly executed if necessary, whereby the interlaminar insulating layers and the conductor circuits are serially built up on both faces thereof in an alternate fashion and in repetition. In this step, a through hole may be formed or may not be formed.

[0126]

Furthermore, when the substrate for mounting an IC chip on which the optical elements are mounted on the opposite side to the side opposed to the multilayered printed circuit board across the substrate and in which the optical paths for transmitting optical signal are formed, through holes penetrating the substrate and the interlaminar insulating layers (hereinafter, referred to as "through holes for optical paths") are formed in the step (8) and further, resin layers for optical paths are formed in the respective through holes for optical paths if necessary.

When the optical paths for transmitting optical signal on the wall faces of which conductor layers are to be formed, through holes for optical paths penetrating the substrate and the interlaminar insulating layers may be formed before forming conductor circuits on the outermost layer and the conductor layers may be formed on the wall faces of the respective through holes for optical paths simultaneously with the formation of the conductor circuits. It is noted that the formation of the conductor layers and that of the conductor circuits on the outermost layer may be carried out separately.

[0127]

The through holes for optical paths may be formed by drilling, a laser treatment or the like.

In addition, the positions at which the through holes for optical paths are formed are not limited to specific ones but

may be appropriately selected based on the design of the conductor circuits, the positions at which the optical elements and the IC chip are mounted and the like.

Furthermore, when the through holes for optical paths are to be formed, they are desirably formed for respective optical elements such as a light receiving element and a light emitting element. Alternatively, they may be formed for respective signal wavelengths.

[0128]

After forming the through holes for optical paths, a desmear treatment may be performed if necessary.

The desmear treatment can be performed by a treatment using a permanganic acid solution, a plasma treatment, a corona treatment or the like. It is noted that when the desmear treatment is conducted, it is possible to remove the resin residue, burrs and the like in the through holes for optical paths, and lower the transmission loss caused by irregular reflection on the wall faces of the optical paths for transmitting optical signal.

[0129]

A roughened face may be formed on the wall of the through holes for optical paths. This is because formation of the roughened face can improve the adhesion with the conductive layer or the resin layer for an optical path.

The roughened face can be formed by dissolving exposed portions generated at the time of forming the through holes for optical paths in the substrate, the interlaminar insulating layer and the like by an acid such as a sulfuric acid, a hydrochloric acid or a nitric acid, an oxidizing agent such as a chromic acid, a chromic sulfide or a permanganate, or the like. Alternatively, the roughened face can be formed by a plasma treatment, a corona treatment or the like. Alternatively, the roughened face may be formed on the surface of the conductive layer after forming the conductive layer.

[0130]

By conducting a curing treatment after filling the uncured resin composition thereinto, it is possible to form optical paths for transmitting optical signal at least a part of which is composed of the resin composition.

A specific method of filling the uncured resin composition is not limited to a specific one but such a method as printing or potting can be used.

When the uncured resin composition is filled by printing, the uncured resin composition may be printed at one time or two or more times. Further, the uncured resin composition may be printed from both faces of the multilayered circuit board.

[0131]

Further, when the uncured resin composition is to be filled, an uncured resin composition slightly larger in quantity than the inner volume of each of the through holes for optical paths may be filled and, after filling the uncured resin composition, an excessive resin composition overflowing the through holes for optical paths may be removed.

The removal of the excessive resin composition can be carried out by grinding or the like. When the excessive resin composition is to be removed, the resin composition may be in a half-cured state or a fully cured state, which state may be appropriately selected based on the material for the resin composition and the like.

By carrying out the aforementioned treatment, it is possible to form an optical path for transmitting optical signal.

[0132]

(9) Next, a solder resist composition layer is formed on each outermost layer of the substrate on which the conductor circuits and the interlaminar insulating layer are formed.

The solder resist composition layer can be formed using a solder resist composition of polyphenylene ether resin, polyolefin resin, fluororesin, thermoplastic elastomer, epoxy resin, polyimide resin or the like.

[0133]

Furthermore, examples of the solder resist composition other than the above-mentioned solder resist composition include a paste-like fluid containing thermosetting resin comprising (meth)acrylate of novolak type epoxy resin, an imidazole curing agent, a bifunctional (meth)acrylic acid ester monomer, (meth)acrylic acid ester polymer with a molecular weight of about 500 to 5000, bisphenol type epoxy resin and the like, a photosensitive monomer such as a multivalent acrylic monomer and a glycol ether type solvent, and its viscosity is desirably prepared to be 1 to 10 Pa・s at 25°C. A commercially available solder resist compositions may be used as well.

[0134]

(10) Next, openings for forming solder bumps (openings for mounting the IC chip and openings for connecting the substrate for mounting an IC chip to the multilayered printed circuit board) and openings for mounting optical elements are formed on the solder resist layer.

The openings for forming solder bumps and the openings for mounting optical elements can be formed by, for example, the same method as that for forming the openings for via-holes, i.e., by exposure and development treatments, a laser treatment or the like.

Moreover, the solder resist layer having openings for forming solder bumps and openings for mounting optical elements may be formed by manufacturing a resin film having openings at desired positions and bonding it at the time of forming the solder resist layer.

[0135]

When the substrate for mounting an IC chip having the optical paths for transmitting optical signal is manufactured, it is desirable to form openings for optical paths communicating with the through holes for optical paths in the solder resist layer. When the openings for optical paths are formed, a resin composition may be filled into each of the openings for optical paths and examples of the resin composition include the same

as that filled into each of the through holes for optical paths and the like.

[0136]

(11) Next, conductor circuit portions exposed by forming the openings for forming solder bumps and the openings for mounting optical elements are covered with corrosion resistant metal such as nickel, palladium, gold, silver and platinum to provide solder pads if necessary. Among the corrosion resistant metallic materials, it is desirable to use nickel-gold, nickel-silver, nickel-palladium, nickel-palladium-gold or the like to form a covering layer.

The covering layer may be formed by plating, vapor deposition, electrodeposition or the like. Among them, plating is desirable from a viewpoint that the covering layer is excellent in evenness at the time of being formed by plating.

In addition, in this step, a covering layer (a conductor layer for establishing electrical connection with the optical elements) is desirably also formed on conductor circuit portions exposed by forming the openings for mounting optical elements.

[0137]

(12) Next, the solder pads are filled with solder paste through a mask having opening parts formed in portions corresponding to the solder pads and then reflow is performed, thereby forming solder bumps.

By forming such solder bumps, it is possible to mount the IC chip through the solder bumps and connect the multilayered printed circuit board to the substrate for mounting an IC chip. It is noted that the solder bumps may be formed if necessary. Even when no solder bumps are formed, it is possible to electrically connect the IC chip to be mounted and the multilayered printed circuit board to be connected through the bumps of the IC chip and the multilayered printed circuit board.

[0138]

(13) Moreover, optical elements (a light receiving element and a light emitting element) are mounted on the solder resist

layer. The mounting of the optical elements may be carried out according to the manner of connecting the optical elements (e.g. wire-bonding, flip-chip bonding or the like). As a specific method of connecting the optical elements by the wire-bonding or the flip-chip bonding, a conventionally well-known method can be used.

[0139]

Further, the optical elements may be mounted so that the optical elements are partially or entirely embedded into the solder resist layer or may be mounted on the surface without embedding them at all.

Accordingly, the magnitude of each of the openings for mounting optical elements formed in the above-mentioned step (10) may be appropriately determined based on the manner of mounting the optical elements.

Further, in this step, after mounting the optical elements, the surroundings thereof may be sealed with resin.

[0140]

Next, the manufacturing method of the multilayered printed circuit board will be described.

(1) First, similarly to the steps (1) to (2) of the manufacturing method of the substrate for mounting an IC chip according to the present invention, conductor circuits are formed on both faces of a substrate and a plated-through hole for connecting the conductor circuits across the substrate are formed. In this step, similarly to the above, a roughened face is formed on the surface of each of the conductor circuits and wall surface of the plated-through hole if necessary.

[0141]

(2) Next, interlaminar insulating layers and conductor circuits are serially built up on both faces of the substrate, on which the conductor circuits are formed, in an alternate fashion and in repetition, if necessary.

Specifically, the interlaminar insulating layers and the conductor circuits may be serially built up in an alternate

fashion and in repetition using the same methods as those used in the steps (3) to (8) of the manufacturing method of the substrate for mounting an IC chip according to the present invention.

In the steps, similarly to the case of manufacturing the substrate for mounting an IC chip, a plated-through hole penetrating the substrate and the interlaminar insulating layers and a cover plated layer may be formed.

It is noted that this step (2), i.e., the step of serially building up the interlaminar insulating layers and the conductor circuits in an alternate fashion and in repetition may be executed only once or a plurality of number of times.

In addition, to form the conductor circuits on the interlaminar insulating layer in this step, the subtractive method may be used similarly to the case of manufacturing the substrate for mounting an IC chip.

[0142]

Further, when the optical waveguides are formed on the interlaminar insulating layer on the opposite side of the multilayered printed circuit board to the side thereof opposed to the substrate for mounting an IC chip across the substrate or the like in a step described later, then through holes for optical paths having resin layers for optical paths formed on the respective interiors thereof and having conductor layers formed on the respective wall faces thereof are formed in this step, if necessary, by the same method as that described in the manufacturing method of the substrate for mounting an IC chip.

It is noted that these through holes for optical paths penetrating the substrate and the like (optical paths for transmitting optical signal) may be formed after forming the optical waveguides in the following step (3).

[0143]

(3) Next, optical waveguides are formed on the substrate on the side opposed to the substrate for mounting an IC chip or on non conductor formed areas on the interlaminar insulating layer.

The optical waveguides can be formed by attaching optical waveguides formed into predetermined shape in advance by adhesive when an inorganic material such as quartz glass is used as a material for the optical waveguides.

Furthermore, the optical waveguides made of the inorganic material can be formed by forming a film out of an inorganic material such as $LiNbO_3$ or $LiTaO_3$ by a liquid-phase epitaxial method, a chemical vapor deposition method (CVD), a molecular beam epitaxial method or the like.

[0144]

Examples of a method of forming the optical waveguides made of a polymer material include (1) a method of bonding a film for forming an optical waveguide formed into a film shape on a removable film or the like onto the interlaminar insulating layer, (2) a method of directly forming the optical waveguide on the interlaminar insulating layer by serially building up a lower cladding, a core and an upper cladding on the interlaminar insulating layer in an alternate fashion and in repetition, and the like.

It is noted that the same method can be used to form the optical waveguides whether the optical waveguides are formed on the removable film or on the interlaminar insulating layer.

Specifically, in order to form the optical waveguides, a method using reactive ion etching, an exposure-development method, a mold formation method, a resist formation method, a combination thereof or the like can be used.

[0145]

When the method by the reactive ion etching is used, the following steps are executed. (i) A lower cladding is formed on the removable film, the interlaminar insulating layer or the like (hereinafter, simply referred to as "removable film or the like"). (ii) A resin composition for a core is applied onto the lower cladding and a curing treatment is conducted, based on necessity, thereby obtaining a resin layer for forming a core. (iii) A resin layer for forming a mask is then formed on the

resin layer for forming a core, and exposure and development treatments are conducted to this resin layer for forming a mask, thereby forming a mask (an etching resist) on the resin layer for forming a core.

[0146]

(iv) Reactive ion etching is conducted to the resin layer for forming a core, thereby removing the resin layer for forming a core in non mask formed areas and forming the core on the lower cladding. (v) Finally, an upper cladding is formed on the lower cladding to cover the core, thus obtaining an optical waveguide.

When the method by this reactive ion etching is used, it is possible to form an optical waveguide excellent in dimension reliability. This method is also excellent in reproducibility.

[0147]

When the exposure-development method is used, the following steps are executed. (i) A lower cladding is formed on the removable film or the like. (ii) A resin composition for a core is applied on this lower cladding and a semi-curing treatment is conducted, based on necessity, thereby forming a layer of the resin composition for forming a core.

[0148]

(iii) Next, a mask having a pattern corresponding to a core formation portion drawn thereon is put on the layer of the resin composition for forming a core and exposure and development treatments are conducted, thereby forming a core on the lower cladding. (iv) Finally, an upper cladding is formed on the lower cladding to cover the core, thus obtaining an optical waveguide.

Since this exposure-development method requires a small number of steps, it can be suitably used when mass-producing optical waveguides. In addition, since this method requires a small number of heat steps, it is possible to make it difficult to cause a stress to occur to the optical waveguide.

[0149]

When the mold formation method is used, the following steps are executed. (i) A lower cladding is formed on the removable

film or the like. (ii) A groove for forming a core is formed in the lower cladding by forming a mold. (iii) A resin composition for a core is filled in the groove by printing and a curing treatment is conducted, thereby forming a core. (iv) Finally, an upper cladding is formed on the lower cladding to cover the core, thus obtaining an optical waveguide.

This mold formation method can be suitably used at the time of mass-producing optical waveguides and optical waveguides excellent in dimension reliability can be formed. This method is also excellent in reproducibility.

[0150]

When the resist formation method is used, the following steps are executed. (i) A lower cladding is formed on the removable film or the like. (ii) A resin composition for a resist is applied onto this lower cladding and exposure and development treatments are conducted, thereby forming a resist for forming a core in non core formed areas on the lower cladding.

[0151]

(iii) Next, a resin composition for a core is applied onto non resist formed areas on the lower cladding. (iv) Further, the resin composition for a core is cured and then the resist for forming a core is peeled off, thereby forming a core on the lower cladding. (v) Finally, an upper cladding is formed on the lower cladding to cover the core, thus obtaining an optical waveguide.

This resist formation method can be suitably used at the time of mass-producing optical waveguides and optical waveguides excellent in dimension reliability can be formed. This method is also excellent in reproducibility.

[0152]

Further, an optical path conversion mirror is formed on the optical waveguides.

The optical path conversion mirror may be formed either before or after attaching to the interlaminar insulating layer. However, it is desirable to form the optical path conversion

mirror before attaching the optical waveguide onto the interlaminar insulating layer except for a case where the optical waveguide is directly formed onto the interlaminar insulating layer. When the optical path conversion mirror is formed in advance, operation is facilitated and there is no possibility of damaging or breaking the other members including the substrate, the conductor circuits and the interlaminar insulating layers that constitute the multilayered printed circuit board.

[0153]

A method of forming the optical path conversion mirror is not limited to a specific one but a conventionally well-known method can be used. Specifically, machining using a diamond saw having a 90°-V-shaped tip end, a blade or a cutter, processing by reactive ion etching, laser abrasion or the like can be conducted to form the optical path conversion mirror.

The method of forming the optical waveguides on the substrate or the outermost interlaminar insulating layer has been described herein. However, when the multilayered printed circuit is manufactured, the optical waveguides are often formed between the substrate and the interlaminar insulating layer or between the interlaminar insulating layers.

[0154]

When the optical waveguides are to be formed between the substrate and the interlaminar insulating layer, the substrate having conductor circuits formed on both faces thereof is formed and then optical waveguides are formed on non conductor formed areas on the substrate similarly to the step (3) in the step (1), and an interlaminar insulating layer is then formed similarly to the step (2), whereby optical waveguides can be formed at the positions.

[0155]

When the optical waveguides are to be formed between the interlaminar insulating layers, at least one interlaminar insulating layer is formed on the substrate having the conductor circuits formed thereon similarly to the steps (1) and (2), then

optical waveguides are formed on the interlaminar insulating layer similarly to the step (3), and the same step as the step (2) is repeatedly executed, whereby optical waveguides can be formed between the interlaminar insulating layers.

[0156]

(4) Next, a solder resist layer is formed on the outermost layer of the multilayered printed circuit board on which the optical waveguides are formed.

The solder resist layer can be formed using the same resin composition as that used to form the solder resist layer of the substrate for mounting an IC chip.

In some cases, the optical waveguides may be formed entirely on the outermost layer of the substrate in the step (3) so as to serve as the solder resist layer.

[0157]

(5) Next, openings for forming solder bumps (openings for mounting the substrate for mounting an IC chip and various surface mount electronic components) and openings for optical paths are formed on a solder resist layer opposed to the substrate for mounting an IC chip.

The formation of the openings for forming solder bumps and openings for optical paths can be performed using the same method as that for forming the openings for forming solder bumps in the manufacturing method of the substrate for mounting an IC chip, i.e., exposure and development treatment, a laser treatment or the like.

The formation of the openings for forming solder bumps and that of the openings for optical paths may be performed simultaneously or separately.

[0158]

Among these methods, it is desirable to select the method of forming the openings for forming solder bumps and the openings for optical paths by applying a resin composition containing, as a material therefor, photosensitive resin and conducting exposure and development treatments at the time of forming the

solder resist layer.

When the openings for optical paths are formed by the exposure and development treatments, there is no possibility of damaging the optical waveguides present under the openings for optical paths at the time of forming the openings.

Alternatively, the solder resist layer having the openings for forming solder bumps and the openings for optical paths may be formed by manufacturing a resin film having openings at desired positions in advance and bonding it in forming the solder resist layer.

When the through holes for optical paths are formed and the optical waveguides are formed on the opposite side to the side opposed to the substrate for mounting an IC chip across the substrate, the openings for optical paths are formed to communicate with the through holes for optical paths at the time of forming the openings for optical paths in this step.

[0159]

Further, if necessary, the solder resist layer on the face of the multilayered printed circuit board opposite to the face thereof opposed to the substrate for mounting an IC chip may be also formed to include openings for forming solder bumps.

This is because external connection terminals can be formed on the solder resist layer on the face of the multilayered printed circuit board opposite to the face thereof opposed to the substrate for mounting an IC chip through a later step.

[0160]

(6) Next, conductor circuit portions exposed by forming the openings for forming solder bumps are covered with corrosion resistant metal such as nickel, palladium, gold, silver and platinum, if necessary, to provide solder pads. Specifically, the same method as that used in the step (11) of the manufacturing method of the substrate for mounting an IC chip according to the present invention may be used so as to form the solder pads.

[0161]

(7) Next, if necessary, an uncured resin composition is

filled into each of the openings for optical paths formed in the step (5) and a curing treatment is then conducted to the resin composition, thereby forming a resin layer for an optical path.

The uncured resin composition filled in this step is desirably equal to that filled into each of the through holes for optical paths and the openings for optical paths in the steps of the manufacturing method of the substrate for mounting an IC chip.

In addition, as mentioned above, even when the through holes for optical paths and the openings for optical paths are formed in order to form optical waveguides on the opposite side to the side opposed to the substrate for mounting an IC chip across the substrate, an uncured resin composition may be filled into the through holes for optical paths and the openings for optical paths. In order to fill the uncured resin composition, one of the following methods may be executed. The first method is: the uncured resin composition is filled into the through holes for optical paths and the openings for optical paths simultaneously. The second method is: after forming the through holes for optical paths in the multilayered circuit board, the uncured resin composition is filled into the through holes for optical paths and cured, a solder resist layer having openings for optical paths is formed and then the uncured resin composition is filled into the openings for optical paths and cured.

[0162]

(8) Next, after filling solder paste into the solder pads through a mask having opening parts formed in portions corresponding to the solder pads, reflow is conducted to form the solder bumps.

By forming such solder bumps, it is possible to mount the substrate for mounting an IC chip and various surface mount electronic components through the solder bumps. It is noted that the solder bumps may be formed if necessary. Even when no solder bumps are formed, it is possible to mount the substrate

for mounting an IC chip and various surface mount electronic components through the bumps of the IC chip and various surface mount electronic components.

On the solder resist layer on the opposite side to the face of the multilayered printed circuit board opposed to the substrate for mounting an IC chip, external connection terminals are not always formed. A PGA (Pin Grid Array) or a BGA (Ball Grid Array) may be provided by disposing pins or forming solder balls if necessary.

Through such steps, it is possible to manufacture the multilayered printed circuit board that constitutes the device for optical communication.

[0163]

In the manufacturing method of the device for optical communication according to the present invention, the substrate for mounting an IC chip and the multilayered printed circuit board are disposed at and fixed to positions such that optical signal can be transmitted between the optical elements of the substrate for mounting an IC chip and the optical waveguides of the multilayered printed circuit board.

In this case, after disposing the substrate for mounting an IC chip and the multilayered printed circuit board to be opposed to each other, solder connection parts are formed by the solder bumps of the substrate for mounting an IC chip and the solder bumps of the multilayered printed circuit board and the substrate for mounting an IC chip and the multilayered printed circuit board are electrically connected to each other and fixed relative to each other. Namely, the substrate for mounting an IC chip and the multilayered printed circuit board are disposed at predetermined positions in predetermined directions, respectively so as to be opposed to each other and reflow is conducted, thereby connecting them to each other.

As mentioned above, the solder bumps for fixing the substrate for mounting an IC chip and the multilayered printed circuit board relative to each other may be formed on only one

of the substrate for mounting an IC chip and the multilayered printed circuit board.

[0164]

Further, in this step, the substrate for mounting an IC chip and the multilayered printed circuit board are connected to each other using their solder bumps. Therefore, even when there is slight positional deviation between the substrate for mounting an IC chip and the multilayered printed circuit board at the time of disposing them to be opposed to each other, it is possible to dispose them at their respective predetermined positions by the self-alignment effect of solders during reflow.

[0165]

Next, a resin composition for sealing is caused to flow between the substrate for mounting an IC chip and the multilayered printed circuit board and a curing treatment is conducted to the resin composition for sealing, thereby forming a sealing resin layer. The resin composition for sealing may be caused to infiltrate between the substrate for mounting an IC chip and the multilayered printed circuit board by applying the resin composition for sealing around the substrate for mounting an IC chip using a dispenser or the like and leaving the resin composition for sealing as it was. Alternatively, the resin composition for sealing may be applied using a syringe.

Examples of the resin composition for sealing include those obtained by appropriately mixing resin components such as the acrylic resin such as PMMA (polymethyl methacrylate), PMMA deuteride and PMMA deuteride fluoride; polyimide resin such as polyimide fluoride; epoxy resin; UV cured epoxy resin; silicone resin such as silicone resin deuteride; polymer produced from benzocyclobutene and the like, with particles to be contained if necessary and various additives such as a curing agent, a defoaming agent, acid anhydrate and a solvent, and the like.

Further, the resin composition for sealing has a transmissivity of desirably 70 % or more, more desirably 90 % for communication wavelength light after being cured.

[0166]

Herein, the viscosity of the resin composition for sealing caused to flow between the substrate for mounting an IC chip and the multilayered printed circuit board and conditions for the curing treatment after the resin composition for sealing is caused to flow therebetween may be appropriately selected based on the composition of the resin composition for sealing, the design of the substrate for mounting an IC chip and the multilayered printed circuit board and the like.

[0167]

Next, an IC chip is mounted on the substrate for mounting an IC chip and, thereafter, the IC chip is sealed with resin if necessary, thereby providing a device for optical communication.

The mounting of the IC chip can be performed by a conventionally well-known method.

Alternatively, the device for optical communication may be obtained by mounting the IC chip before connecting the substrate for mounting an IC chip to the multilayered printed circuit board and, then, connecting the substrate for mounting an IC chip on which the IC chip is mounted to the multilayered printed circuit board.

As the resin composition used to seal the IC chip with resin, a conventionally well-known resin composition for sealing an IC chip can be used and particles may be mixed into this resin composition.

[0168]

[EXAMPLES]

The present invention will be described in more detail below.

(Example 1)

A. Manufacturing of substrate for mounting an IC chip

A-1. Manufacturing of resin film for interlaminar insulating layer

30 parts by weight of Bisphenol A type epoxy resin (epoxy

equivalent 469, Epikote 1001 made by Yuka Shell Epoxy Co.), 40 parts by weight of cresol novolak type epoxy resin (epoxy equivalent 215, Epichlon N-673 made by Dainippon Ink and Chemicals, Inc.), and 30 parts by weight of phenol novolak resin containing triaging structure (phenolic hydroxy equivalent 120, Phenolite KA-7052 made by Dainippon Ink and Chemicals, Inc.) were dissolved while being heated in 20 parts by weight of ethyl diglycol acetate and 20 parts by weight of solvent naphtha under stirring condition, followed by the addition of 15 parts by weight of epoxy-terminated polybutadiene rubber (made by Nagase Chemicals Ltd.; Denalex R-45EPT) and 1.5 parts by weight of a pulverized product of 2-phenyl-4,5-bis(hydroxymethyl)imidazole, 2 parts by weight of a finely pulverized silica, and 0.5 parts by weight of a silicone based defoaming agent to prepare an epoxy resin composition.

After the obtained epoxy resin composition was applied to a 38 μm-thick PET film so as to adjust the thickness after drying to be 50 μm by a roll coater, the resulting film was dried at 80 to 120°C for 10 minutes to produce a resin film for an interlaminar insulating layer.

[0169]

A-2. Preparation of resin composition for filling through hole

A container was loaded with 100 parts by weight of bisphenol F type epoxy monomer (YL 983 U made by Yuka Shell Epoxy Co.; molecular weight: 310), 170 parts by weight of a SiO_2 spherical particles coated with a silane coupling agent and having an average particle diameter of 1.6 μm and a diameter of the maximum particle of 15 μm or less (made by Admatechs Co., Ltd.; CRS 1101-CE), and 1.5 parts by weight of a leveling agent (Perenol S4 made by San Nopco Ltd.) and they were stirred and mixed to prepare a resin filler with a viscosity of 45 to 49 Pa・s at 23 ± 1°C. As a curing agent, 6.5 parts by weight of an imidazole curing agent (made by Shikoku Chemicals Corp.; 2E4MZ-CN) was employed.

[0170]

A-3. Manufacturing of substrate for mounting IC chip

(1) A copper-clad laminated board composed of an insulating substrate 21 made of a 0.8 mm-thick glass epoxy resin or BT (bismaleimide-triaging) resin, with a 18 μm-thick copper foil 28 laminated on both faces of the substrate 21 was used as a starting material (see Fig. 4(a)). First, the copper-clad laminated board was drilled to bore holes and then, an electroless plating treatment was carried out and pattern etching was carried out to form conductor circuits 24 and a plated-through hole 29 on both faces of the substrate 21 (see Fig. 4(b)).

[0171]

(2) The substrate having the plated-through hole 29 formed therein and the conductor circuits 24 formed thereon was washed with water and dried, then subjected to a blackening treatment using an aqueous solution containing NaOH (10 g/l), $NaClO_2$ (40 g/l), Na_3PO_4 (6 g/l) as a blackening bath (oxidizing bath) and a reducing treatment using an aqueous solution containing NaOH (10 g/l) and $NaBH_4$ (6 g/l) as a reducing bath to form roughened faces (not shown) on the entire surfaces of the conductor circuits 24 including the plated-through hole 29.

[0172]

(3) After the resin filler described in A-2 was prepared, a layer of resin filler 30′ was formed inside the plated-through hole 29, non conductor formed areas and the peripheral parts of the conductor circuits 24 on one face of the substrate 21 by the following method within 24 hours after the preparation.

That is, first, the resin filler was pushed in the plated-through hole using a squeegee and then dried under conditions of 100°C for 20 minutes. Next, a mask having openings corresponding to the non conductor formed areas was put on the substrate, and the resin filler was also filled into the concave non conductor formed areas using the squeegee and dried under conditions of 100°C for 20 minuets, thereby forming the layer of resin filler 30′ (see Fig. 4(c)).

[0173]

(4) One face of the substrate for which the treatment (3) was just finished was ground by belt sander grinding using #600 belt grinding paper (made by Sankyo Chemical Engineering Co.) so as not to leave the resin filler 30′ on the surfaces of the conductor circuits 24 and the land surface of the plated-through holes 29 and then, buff grinding was carried out to remove scratches caused by the belt sander grinding. A series of such grinding steps were conducted to the other face of the substrate in the same manner.

Next, heat treatments at 100°C for 1 hour, at 120°C for 3 hours, at 150°C for 1 hour and 180°C for 7 hours were carried out, respectively, to form a resin filler layer 30.

[0174]

In such a manner, the surface layer part of the resin filler layer 30 formed in the plated-through hole 29 and the non conductor formed areas and the surfaces of the conductor circuits 24 were flattened, thus obtaining an insulating substrate wherein: the resin filler 30 and the side faces of the conductor circuits 24 were firmly stuck to each other through the roughened faces; and the inner wall face of the plated-through hole 29 and the resin filler 30 were also firmly stuck to each other through the roughened faces (see Fig. 4(d)). By this step, the surface of the resin filler layer 30 was flush with the surfaces of the conductor circuits 24.

[0175]

(5) After the substrate was washed with water and degreased with an acid, soft etching was carried out and etchant was sprayed on both faces of the substrate to etch the surfaces of the conductor circuits 24 and the land surface of the plated-through hole 29, thereby forming roughened faces (not shown) on the entire surfaces of the conductor circuits 24. As the etchant, etchant (made by Meck Co.; Meck etch bond) containing 10 parts by weight of an imidazole copper(II) complex and 7 parts by weight of glycolic acid, and 5 parts by weight of potassium chloride was used.

[0176]

(6) Next, a resin film for an interlaminar insulating layer with a slightly larger size than that of the substrate produced in the A-1 was put on the substrate, temporarily pressure-bonded under conditions of 0.4 MPa pressure, 80°C temperature, and 10-second pressure bonding period and cut. Thereafter, the film was bonded by the following method using a vacuum laminator device to thereby form an interlaminar insulating layer 22 (see Fig. 4(e)).

That is, the resin film for an interlaminar insulating layer was actually pressure-bonded on the substrate under conditions of 65 Pa degree of vacuum, 0.4 MPa pressure, 80°C temperature and 60-second pressure bonding period, and the resin film was further thermally cured at 170°C for 30 minutes.

[0177]

(7) Next, openings for via-holes 26 with 80 μm diameter were formed in the interlaminar insulating layers 22 by a CO_2 gas laser of 10.4 μm wavelength through a 1.2 mm-thick mask having through holes therein in conditions of a beam diameter of 4.0 mm, a top hat mode, a pulse interval of 8.0 μs, 1.0 mm-diameter of the through holes of the mask and one shot (see Fig. 5(a)).

[0178]

(8) The substrate in which the openings for via-holes 26 were formed was immersed in a solution containing 60 g/l of permanganic acid at 80°C for 10 minutes to dissolve and remove epoxy resin particles existing on the surfaces of the interlaminar insulating layers 22, thus forming the roughened faces (not shown) on the interlaminar insulating layers 22 including the inner wall faces of the openings for via-holes 26.

[0179]

(9) Next, the substrate completed with the treatment was immersed in neutralizer (made by Shiplay Co., Inc.) and washed with water.

Further, a palladium catalyst was attached to the surface

of the substrate subjected to the roughening treatment (roughening depth of 3 μm), whereby a catalyst core was attached to the surfaces of the interlaminar insulating layers 22 (including the inner wall faces of the openings for via-holes 26) (not shown). That is, the catalyst was attached by immersing the substrate in a catalytic solution containing palladium chloride ($PdCl_2$) and stannous chloride ($SnCl_2$) to precipitate metal.

[0180]

(10) Next, the substrate was immersed in an electroless copper plating solution having the following composition to form an electroless copper plating film 32 having a thickness of 0.6 to 3.0 μm on the surface of each interlaminar insulating layer 22 (including the inner wall faces of the openings for via-holes 26) (see Fig. 5(b)).

[0181]

[Electroless plating solution]

$NiSO_4$	0.003 mol/l
Tartaric acid	0.200 mol/l
Copper sulfate	0.030 mol/l
HCHO	0.050 mol/l
NaOH	0.100 mol/l
α,α'-bipyridyl	100 mg/l
Polyethylene glycol (PEG)	0.10 g/l

[Electroless plating condition]

30°C liquid temperature and 40 minutes

[0182]

(11) Next, a commercially available photosensitive dry film was bonded to the substrate on which the electroless copper plating films 32 were formed, a mask was put thereon and exposure with 100 mJ/cm^2 and development with an aqueous 0.8% sodium carbonate solution were carried out, thereby forming a plating resist 23 having a thickness of 20 μm (see Fig. 5(c)).

[0183]

(12) Next, the substrate was washed with water at 50°C

to be degreased, washed with water at 25°C, and further washed with sulfuric acid. Thereafter, the substrate was subjected to electroplating under the following conditions, thereby forming an electroplating copper film 33 having a 20 μm-thickness in non plating resist 23 formed areas (see Fig. 5(d)).

[0184]

[Electroplating solution]

[Electroplating solution]

Sulfuric acid	2.24 mol/l
Copper sulfate	0.26 mol/l
Additive	19.5 ml/l
(Cupracid GL made by Atotech Co.)	
[Electroplating conditions]	
Current density	1 A/dm^2
Time	65 minutes
Temperature	22±2°C

[0185]

(13) After peeling off the plating resists 23 with 5% NaOH, the electroless copper plating film under the plating resist 23 was etched, dissolved and removed with a solution mixture of sulfuric acid and hydrogen peroxide, thus forming conductor circuits 25 (including via-holes 27) each composed of the electroless copper plating film 32 and the electroplating copper film 33 and having a thickness of 18 μm (see Fig. 6(a)).

[0186]

(14) Next, the steps (5) to (12) were repeated, thereby building up upperlevel interlaminar insulating layers and conductor circuits in an alternate fashion and in repetition (see Figs. 6(b) and 6(c)).

Further, using the same etchant (Meck etch bond) as that used in the step (5), roughened faces (not shown) on the surfaces of the conductor circuits 25 (including the via-holes 27).

[0187]

(15) Next, the container was loaded with: 46.67 parts by weight of an oligomer provided with a photosensitivity (molecular

weight: 4000) obtained by acrylating 50% of the epoxy group of cresol novolak type epoxy resin (made by Nippon Kayaku Co., Ltd.), dissolved in diethylene glycol dimethyl ether (DMDG) to be 60% by weight concentration; 15.0 parts by weight of bisphenol A type epoxy resin (trade name: Epikote 1001 made by Yuka Shell Epoxy Co.) dissolved in methyl ethyl ketone to be 80% by weight concentration; 1.6 parts by weight of imidazole curing agent (trade name: 2E4MZ-CN made by Shikoku Chemicals Corp.); 4.5 parts by weight of a polyvalent acrylic monomer, which was a photosensitive monomer (trade name: R604, made by Nippon Kayaku Co., Ltd.); 1.5 parts by weight of a similarly polyvalent acrylic monomer (trade name: DPE 6 A made by Kyoei Chemical Co., Ltd.); and 0.71 parts by weight of the dispersion type defoaming agent (made by San Nopco Ltd.; S-65). They were stirred and mixed to prepare a mixture composition. 2.0 parts by weight of benzophenone (made by Kanto Chemical Co., Inc.) as photoinitiator and 0.2 parts by weight of Michler's ketone (made by Kanto Chemical Co., Inc.) as photosensitizer were added to the mixture composition, thereby obtaining a solder resist composition prepared to have a viscosity of 2.0 Pa·s at 25°C.

The viscosity measurement was carried out using a rotor No. 4 in the case of 60 min^{-1} (rpm) and a rotor No. 3 in the case of 6 min^{-1} (rpm) using a B-type viscometer (made by Tokyo Instruments Co. Ltd., DVL-B type).

[0188]

(16) Next, the solder resist composition was applied by 30 μm thickness to both faces of the substrate having the interlaminar resin insulating layers 22 and the conductor circuits 25 (including the via-holes 27) formed thereon and dried under conditions of 70°C for 20 minutes and 70°C for 30 minutes, thereby forming a solder resist composition layer 34' (see Fig. 7(a)).

[0189]

(17) Next, a 5 mm-thick photomask on which a pattern of openings for forming solder bumps and openings for mounting

optical elements (a light receiving element and a light emitting element) was drawn was closely stuck to one of the solder resist composition layers, exposed with UV rays of 1000 mJ/cm^2 and developed with a DMTG solution.

Further, heat treatments were conducted under conditions of 80°C for 1 hour, 100°C for 1 hour, 120°C for 1 hour and 150°C for 3 hours, respectively, to cure the solder resist composition layer, thereby forming a solder resist layer 34 having openings for forming solder bumps 35, openings for mounting optical elements 31 and a thickness of 20 μm. It is noted that the diameter of the openings for forming solder bumps 35 was 150 μm and the distance between the openings was 250 μm.

Further, a photomask on which a pattern of IC chip mounting openings was drawn was closely stuck to the other solder resist composition layer and subjected to exposure and development under the same exposure and development conditions as those mentioned above, thereby openings for mounting IC chips 35 (see Fig. 7(b)).

It is noted that the diameter of the openings for forming solder bumps was normally about 50 to 200 μm and the distance between the openings was normally 100 to 250 μm.

[0190]

(18) Next, the substrate on which the solder resist layers 34 were formed was immersed in an electroless nickel plating solution having pH 4.5 and containing nickel chloride (2.3×10^{-1} mol/l), sodium hypophosphite (2.8×10^{-1} mol/l) and sodium citrate (1.6×10^{-1} mol/l) for 20 minutes, thereby forming a 5 μm-thick nickel plated layer in the openings for forming solder bumps 35 and the openings for mounting optical elements 31. Further, the resultant substrate was immersed in an electroless gold plating solution containing potassium gold cyanide (7.6×10^{-3} mol/l), ammonium chloride (1.9×10^{-1} mol/l), sodium citrate (1.2×10^{-1} mol/l) and sodium hypophosphite (1.7×10^{-1} mol/l) under conditions of 80°C for 7.5 minutes, to form a 0.03 μm-thick gold plated layer on the nickel plated layer, thus obtaining solder pads 36 and pads for connecting optical elements 42.

[0191]

(19) Next, a light receiving element 38 and a light emitting element 39 were attached into the openings for mounting optical elements 31 on which the solder resist layer 34 was formed using resin for die-bonding while aligning a light receiving part and a light emitting part.

As the light receiving element 38, an optical element comprising InGaAs was used. As the light emitting element 39, an optical element comprising InGaAsP was used.

Next, the light receiving element 38 and the light emitting element 39 were connected to the pads for connecting optical elements 42 exposed to the bottoms of the respective openings for mounting optical elements 31 by wire-bonding. As wires 45 herein, Au containing wires were used.

[0192]

Next, the surroundings of the optical element 38 and the light emitting element 39 were sealed with resin by the following method.

That is, an uncured resin composition containing thermosetting epoxy resin, particles having an average particle size of 5 μm with particle size distribution of 1 to 10 μm, acid anhydride, a defoaming agent and a curing agent was filled into each of the openings for mounting optical elements 31 in which the optical elements 38 and 39 were mounted, respectively, and a curing treatment was then conducted to the resin composition, thereby sealing the surroundings of the optical elements with resin 47.

[0193]

(20) Next, solder paste was printed in the openings for forming solder bumps 35 formed in each solder resist layer 34 and reflow was conducted at 200°C, thereby forming solder bumps 37. Further, solder bumps were similarly formed on the openings for mounting IC chips, thus obtaining a substrate for mounting an IC chip.

[0194]

B. Manufacturing of multilayered printed circuit board

B-1. Manufacturing of resin film for interlaminar resin insulating layer

A resin film for an interlaminar resin insulating layer was prepared using the same method as that used in A-1.

B-2. Preparation of resin composition for filling through hole

A resin composition for filling a through hole was prepared using the same method as that used in A-2.

[0195]

B-3. Manufacturing of multilayered printed circuit board

(1) A copper-clad laminated board composed of an insulating substrate 1 made of a 0.6 mm-thick glass epoxy resin or BT resin, with a 18 μm-thick copper foil 8 laminated on both faces of the substrate 1 was used as a starting material (see Fig. 9(a)). First, the copper-clad laminated board was drilled to bore holes and, then, an electroless plating treatment was carried out and pattern etching was carried out to form conductor circuits 4 and a plated-through hole 9 on both faces of the substrate 1 (see Fig. 9(b)).

[0196]

(2) The substrate having the plated-through hole 9 formed therein and the conductor circuits 4 formed thereon was washed with water and dried, then etchant (made by Meck Co.; Meck etch bond) was sprayed to the substrate, thereby forming roughened faces (not shown) on the surfaces of the conductor circuits 4 including the plated-through hole 9.

[0197]

(3) After the resin filler described in B-2 was prepared, a layer of resin filler 10′ was formed inside the plated-through hole 9, non conductor formed areas and the peripheral parts of the conductor circuits 4 on one side of the substrate 1 by the following method within 24 hours after the preparation.

That is, first, the resin filler was pushed in the plated-through hole using a squeegee and then dried under

conditions of 100°C for 20 minutes. Next, a mask having openings corresponding to the non conductor formed areas was put on the substrate, and the resin filler was also filled into the concave non conductor formed areas using the squeegee and dried under conditions of 100°C for 20 minuets, thereby forming the layer of resin filler 10' (see Fig. 9(c)).

[0198]

(4) One face of the substrate for which the treatment (3) was just finished was ground by belt sander grinding using #600 belt grinding paper (made by Sankyo Chemical Engineering Co.) so as not to leave the resin filler 10' on the surfaces of the conductor circuits 4 and the land surface of the plated-through hole 9 and then, buff grinding was carried out to remove scratches caused by the belt sander grinding. A series of such grinding steps were conducted to the other face of the substrate in the same manner.

Next, heat treatments at 100°C for 1 hour, at 120°C for 3 hours, at 150°C for 1 hour and 180°C for 7 hours were carried out, respectively, to form a resin filler layer 10.

[0199]

In such a manner, the surface layer part of the resin filler 10 formed in the plated-through hole 9 and the non conductor formed areas, the surfaces of the conductor circuits 4 were flattened and the resin filler 10 and the side faces of the conductor circuits 4 were firmly stuck to each other through the roughened faces, and the inner wall face of the plated-through hole 9 and the resin filler 10 were also firmly stuck to each other through the roughened face, thus obtaining an insulating substrate (see Fig. 9(d)). By this step, the surface of the resin filler layer 10 was flush with the surfaces of the conductor circuits 4.

[0200]

(5) After the substrate was washed with water and degreased with an acid, soft etching was carried out and etchant was sprayed on both faces of the substrate to etch the surfaces of the conductor

circuits 4 and the land surface and inner wall of the plated-through hole 9, thereby forming roughened faces (not shown) on the entire surfaces of the conductor circuits 4. As the etchant, Meck etch bond made by Meck Co. was used.

[0201]

(6) Next, a resin film for the interlaminar resin insulating layer with a slightly larger size than that of the substrate produced in the B-1 was put on the substrate, temporarily pressure-bonded under conditions of 0.4 MPa pressure, 80°C temperature, and 10-second pressure bonding period and cut. Thereafter, the film was bonded by the following method using a vacuum laminator device to thereby form an interlaminar resin insulating layer 2 (see Fig. 10(a)). That is, the resin film for the interlaminar resin insulating layer was actually pressure-bonded on the substrate under conditions of 65 Pa degree of vacuum, 0.4 MPa pressure, 80°C temperature and 60-second pressure bonding period, and the resin film was further thermally cured at 170°C for 30 minutes.

[0202]

(7) Next, openings for via-holes 6 with 80 μm diameter were formed in the interlaminar resin insulating layers 2 by a CO_2 gas laser of 10.4 μm wavelength through a 1.2 mm-thick mask having through holes therein in conditions of a beam diameter of 4.0 mm, a top hat mode, a pulse interval of 8.0 μs, 1.0 mm-diameter of the through holes of the mask and one shot. (see Fig. 10(b)).

[0203]

(8) The substrate in which the openings for via-holes 6 were formed was immersed in a solution containing 60 g/l of permanganic acid at 80°C for 10 minutes to dissolve and remove epoxy resin particles existing on the surfaces of the interlaminar resin insulating layers 2, thus forming the roughened faces (not shown) on the surfaces of the interlaminar resin insulating layers 2 including the inner wall faces of the openings for via-holes 6.

[0204]

(9) Next, the substrate completed with the treatment was immersed in neutralizer (made by Shiplay Co., Inc.) and washed with water.

Further, a palladium catalyst was attached to the surface of the substrate subjected to the roughening treatment (roughening depth of 3 μm), whereby a catalyst core was attached to the surfaces of the interlaminar resin insulating layers 2 (including the inner wall faces of the openings for via-holes 6) (not shown). That is, the catalyst was attached by immersing the substrate in a catalytic solution containing palladium chloride ($PdCl_2$) and stannous chloride ($SnCl_2$) to precipitate metal.

[0205]

(10) Next, the substrate was immersed in an electroless copper plating solution having the following composition to form a electroless copper plating film 12 having a thickness of 0.6 to 3.0 μm on the surface of each interlaminar resin insulating layer 2 (including the inner wall faces of the openings for via-holes 6) (see Fig. 10(c)).

It is noted that the used electroless plating solution and the electroless plating conditions were the same as those in the step (10) in the manufacturing of the substrate for mounting an IC chip.

[0206]

(11) The substrate on which the electroless plating films 12 were formed was washed with water and electroplating was then carried out, thereby forming an electroless copper plating film 13 having a thickness of 20 μm entirely on each electroless plating film 12 (see Fig. 11(a)).

It is noted that the used electroless plating solution and the electroless plating conditions were the same as those in the step (12) in the manufacturing of the substrate for mounting an IC chip.

[0207]

(12) Next, a commercially available photosensitive dry film was bonded to the substrate on which the electroless copper plating films 13 were formed, a mask was put thereon and exposure with 100 mJ/cm^2 and development with an aqueous 0.8% sodium carbonate solution were carried out, thereby forming an etching resist 3 (see Fig. 11(b)).

[0208]

(13) Next, the electroplating copper film and the electroless plating film under the non etching resist formed areas were etched with a solution mixture of sulfuric acid and hydrogen peroxide, thereby dissolving and removing these films, and the etching resist was peeled off with 5% NaOH solution, thereby forming conductor circuits 7 (including the via-holes 5) each comprising the electroless copper plating film 12 and the electroplating copper film 13 (see Fig. 11(c)).

Further, using etchant (Meck etch bond), roughened faces (not shown) were formed on the respective conductor circuits 5 (including the via-holes 7).

[0209]

(14) Next, optical waveguides 18 (18a, 18b) having optical path conversion mirrors 19 (19a, 19b) were formed at predetermined positions by the following method, respectively (see Fig. 12(a)).

That is, a film-shaped optical waveguide (width: 25 μm, thickness: 25 μm) which was made of PMMA and on which 45°-the optical conversion mirror 19 was formed in advance using a diamond saw having a 90°-V-shaped tip end was bonded so that the side face of the optical waveguide on the other end on the non optical path conversion mirror formed side was aligned to the side face of the interlaminar resin insulating layer.

The bonding of each optical waveguide was performed by applying adhesive comprising thermosetting resin onto the bonded face of the optical waveguide to the interlaminar resin insulating layer by a thickness of 10 μm, pressure-bonding the adhesive and curing the adhesive at 60°C for 1 hour.

In this example, curing was conducted under condition of 60°C/1 hour. In some cases, step curing may be conducted. When the step curing is conducted, no stress occurred due to the optical waveguide at the time of bonding the optical waveguide.

[0210]

(15) Next, a solder resist composition was prepared similarly to the step (15) in the manufacturing of the substrate for mounting an IC chip, the solder resist composition was applied onto both faces of the substrate by a thickness of 35 μm and dried under conditions of 70°C for 20 minutes and 70°C for 30 minutes, thereby forming a solder resist layer 14' (see Fig. 12(b)).

[0211]

(16) Next, a 5 mm-thick photomask on which a pattern of openings for forming solder bumps and openings for optical paths was drawn was closely stuck to one face of the substrate, exposed with UV rays of 1000 mJ/cm^2 and developed with a DMTG solution, thereby forming openings having a diameter of 150 μm at intervals of 250 μm.

Further, heat treatments were conducted under conditions of 80°C for 1 hour, 100°C for 1 hour, 120°C for 1 hour and 150°C for 3 hours, respectively, to cure the solder resist layer, thereby forming a solder resist layer 14 having openings for forming solder bumps 15, openings for optical paths 11 (11a, 11b) and a thickness of 20 μm (see Fig. 13(a)).

[0212]

(17) Next, similarly to the step (18) in the manufacturing of the substrate for mounting an IC chip, a nickel plated layer and a gold plated layer were formed, thereby obtaining solder pads 16.

[0213]

(18) Solder paste was printed in each of the openings for forming solder bumps 15 formed in the solder resist layer 14, and reflow was conducted at 200°C, thereby forming solder bumps 17 in the respective openings for forming solder bumps 15, thus

obtaining a multilayered printed circuit board (see Fig. 13(b)).
[0214]

C. Manufacturing of device for IC mounting optical communication

First, an IC chip was mounted on the substrate for mounting an IC chip manufactured through the steps in A, the IC chip was then sealed with resin, thereby obtaining a substrate for mounting an IC chip.

Thereafter, this substrate for mounting an IC chip and the multilayered printed circuit board manufactured through the steps in B were disposed at predetermined positions to be opposed to each other, respectively, and reflow was conducted at 200°C, thereby connecting the solder bumps of the substrate and the board to form solder connection parts.
[0215]

Next, an uncured resin composition for sealing was filled between the multilayered printed circuit board and the substrate for mounting an IC chip which were connected through the solder connection parts and a curing treatment was conducted to the resin composition for sealing, thereby forming a sealing resin layer and thus obtaining a device for optical communication (see Fig. 1).

As the resin composition for sealing, a resin composition containing thermosetting epoxy resin, particles having an average particle size of 5 μm with a particle size distribution of 1 to 10 μm, acid anhydride, defoaming agent and curing agent was used. In addition, the viscosity of the resin composition for sealing was 5 Pa•s at 5 min^{-1} (rpm)/25°C.

Further, the transmissivity of the formed sealing resin layer was 85 %.

It is noted that the viscosity of the resin composition for sealing is normally about 1 to 10 Pa•s at 5 min^{-1} (rpm)/25°C.
[0216]

(Example 2)

A device for optical communication was manufactured

similarly to Example 1 except that at the time of forming the optical waveguides, optical waveguides each comprising a lower cladding, a core and an upper cladding and having an optical path conversion mirror formed thereon were formed on the outermost interlaminar resin insulating layer using the following method at the time of forming the optical waveguides in the step (14) in the manufacturing of the multilayered printed circuit board in Example 1.

Each of the optical waveguides was formed as follows. PMMA for forming a lower cladding was first applied to a predetermined position on the outermost interlaminar resin insulating layer to form a film and the resultant film was thermally cured, thereby forming a lower cladding. Thereafter, PMMA for forming a core was applied onto the lower cladding to form a film and the resultant film was thermally cured, thereby forming a core layer.

Thereafter, a resist was applied onto the surface of the core layer, a resist pattern was formed by photolithography, and patterning was carried out into core shape by reactive ion etching, thereby forming a core on the lower cladding.

Next, PMMA for forming an upper cladding was applied onto the core and thermally cured, thereby forming an upper cladding on the core and thus obtaining an optical waveguide. Thereafter, a 45°-optical path conversion mirror was formed on one end of this optical waveguide by machining.

It is noted that the PMMA for forming a lower cladding and the PMMA for forming an upper cladding were equal in composition.

[0217]

(Example 3)

A device for optical communication was manufactured similarly to Example 1 except that openings for forming solder bumps having a diameter of 70 μm at intervals of 127 μm in each of the step (17) in the manufacturing of the substrate for mounting an IC chip and the step (16) in the manufacturing of the multilayered printed circuit board in Example 1.

[0218]

For each of the devices for IC mounting optical communication in Examples 1 to 3 thus obtained, an optical fiber was attached to the exposed face of the optical waveguide, opposed to the light receiving element, from the multilayered printed circuit board, a detector was attached in place of the light receiving element, optical signal was transmitted through the optical fiber and the optical signal was detected by the detector. As a result, a desired optical signal could be detected, thus demonstrating that each of the devices for IC mounting optical communication manufactured in the examples had sufficiently satisfactory performance as a device for optical communication.

[0219]

Furthermore, the waveguide loss between the light emitting element mounted on the substrate for mounting an IC chip and the optical waveguide opposed to this light emitting element and formed on the multilayered printed circuit board was measured by the following method. As a result, the waveguide loss was 0.3 dB/cm or less, thus demonstrating that it was possible to sufficiently transmit optical signal.

The measurement of the waveguide loss was conducted by attaching an optical fiber to the end portion of the optical waveguide for light reception, attaching a power meter on the light emitting element-side end portion of the optical path for transmitting optical signal through the optical fiber, transmitting optical signal with a measured wavelength of 850 nm from the optical fiber attached to the optical waveguide, and detecting the optical signal transmitted through the optical waveguide for light reception and the optical path for transmitting optical signal using the power meter.

[0220]

Moreover, in each of the devices for optical communication obtained in Examples 1 to 3, the positional deviation of the optical elements (light receiving element and light emitting element) and the optical waveguides from desired positions was

hardly observed.

[0221]

[EFFECTS OF THE INVENTION]

As mentioned above, the device for optical communication according to the present invention comprises a substrate for mounting an IC chip on which a light receiving element and a light emitting element are mounted at respective predetermined positions and a multilayered printed circuit board on which optical waveguides are formed at respective predetermined positions. Therefore, the connection loss between the mounted optical components is low and connection reliability as the device for optical communication is excellent.

[0222]

Further, as mentioned above, in the device for optical communication according to the present invention, a sealing resin layer is formed and dust, external matters and the like floating in the air are prevented from entering between each optical element and each optical waveguide and the optical signal transmission is not hampered by the dust, external matters and the like. Therefore, reliability as the device for optical communication is excellent.

Moreover, by forming the sealing resin layer, the sealing resin layer can serve to moderate the stress generated between the substrate for mounting an IC chip and the multilayered printed circuit board and make it more difficult to cause the positional deviation of the optical elements and the optical waveguides. Therefore, the device for optical communication according to the present invention is excellent in reliability.

[0223]

In the manufacturing method of a device for optical communication according to the present invention, after disposing and fixing a substrate for mounting an IC chip and a multilayered printed circuit board at and to respective predetermined positions, a sealing resin layer is formed between them. Therefore, it is possible to suitably manufacture a device

for optical communication capable of preventing dust, foreign matters and the like floating in the air from entering between the optical elements and the optical waveguides and capable of preventing optical signal transmission from being hampered.

[0224]

Further, by forming the sealing resin layer between the substrate for mounting an IC chip and the multilayered printed circuit board, the sealing resin layer can serve to moderate the stress generated between the substrate for mounting an IC chip and the multilayered printed circuit board due to the difference in thermal expansion coefficient therebetween and make it more difficult to cause the positional deviation of the optical element and the optical waveguide.

Accordingly, the manufacturing method of a device for optical communication according to the present invention can suitably manufacture a device for optical communication excellent in reliability.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a cross-sectional view schematically showing one embodiment of a device for optical communication according to the present invention.

[Fig. 2]

Fig. 2 is a cross-sectional view schematically showing another embodiment of the device for optical communication according to the present invention.

[Fig. 3]

Fig. 3 is a cross-sectional view schematically showing another embodiment of the device for optical communication according to the present invention.

[Fig. 4]

Fig. 4 is a cross-sectional view schematically showing part of steps of manufacturing a substrate for mounting an IC chip that constitutes the device for optical communication according to the present invention.

[Fig. 5]

Fig. 5 is a cross-sectional view schematically showing part of the steps of manufacturing the substrate for mounting an IC chip that constitutes the device for optical communication according to the present invention.

[Fig. 6]

Fig. 6 is a cross-sectional view schematically showing part of the steps of manufacturing the substrate for mounting an IC chip that constitutes the device for optical communication according to the present invention.

[Fig. 7]

Fig. 7 is a cross-sectional view schematically showing part of the steps of manufacturing the substrate for mounting an IC chip that constitutes the device for optical communication according to the present invention.

[Fig. 8]

Fig. 8 is a cross-sectional view schematically showing part of the steps of manufacturing the substrate for mounting an IC chip that constitutes the device for optical communication according to the present invention.

[Fig. 9]

Fig. 9 is a cross-sectional view schematically showing part of steps of manufacturing a multilayered circuit board that constitutes the device for optical communication according to the present invention.

[Fig. 10]

Fig. 10 is a cross-sectional view schematically showing part of the steps of manufacturing the multilayered circuit board that constitutes the device for optical communication according to the present invention.

[Fig. 11]

Fig. 11 is a cross-sectional view schematically showing part of the steps of manufacturing the multilayered circuit board that constitutes the device for optical communication according to the present invention.

[Fig. 12]

Fig. 12 is a cross-sectional view schematically showing part of the steps of manufacturing the multilayered circuit board that constitutes the device for optical communication according to the present invention.

[Fig. 13]

Fig. 13 is a cross-sectional view schematically showing part of the steps of manufacturing the multilayered circuit board that constitutes the device for optical communication according to the present invention.

[Fig. 14]

Fig. 14 is a cross-sectional view schematically showing another embodiment of the device for optical communication according to the present invention.

[Fig. 15]

Fig. 15 is a cross-sectional view schematically showing another embodiment of the device for optical communication according to the present invention.

[Explanation of Symbols]

100 multilayered printed circuit board
101 substrate
102 interlaminar resin insulating layer
104 conductor circuit
107 via-hole
109 plated-through hole
111 opening for optical path
114 solder resist layer
118 optical waveguide
119 optical path conversion mirror
120 substrate for mounting IC chip
121 substrate
122 interlaminar resin insulating layer
124 conductor circuit
127 via-hole
129 plated-through hole

131 openings for mounting optical element
134 solder resist layer
137 solder connection part
138 light receiving element
139 light emitting element
140 IC chip
142 conductor layer
150 device for optical communication
160 sealing resin layer

[Document Name] Abstract

[Abstract]

[Subject] To privide a device for optical communication in which dust, foreign matters and the like floating in the air do not enter between the optical element and the optical waveguide because the sealing resin layer is formed between the substrate for mounting an IC chip and the multilayered printed circuit board, and thus the transmission of optical signal of the device for optical communication can be prevented from being hampered by the dust, the foreign matters and the like.

[Constitution] A device for optical communication including: a substrate for mounting an IC chip on which at least an optical element is mounted; and a multilayered printed circuit board on which at least an optical waveguide is formed, the device for optical communication being constituted to be able to transmit optical signal between said optical waveguide and said optical element, wherein a sealing resin layer is formed between said substrate for mounting an IC chip and said multilayered printed circuit board.

[Selective Figure] Fig. 1

FIG.1

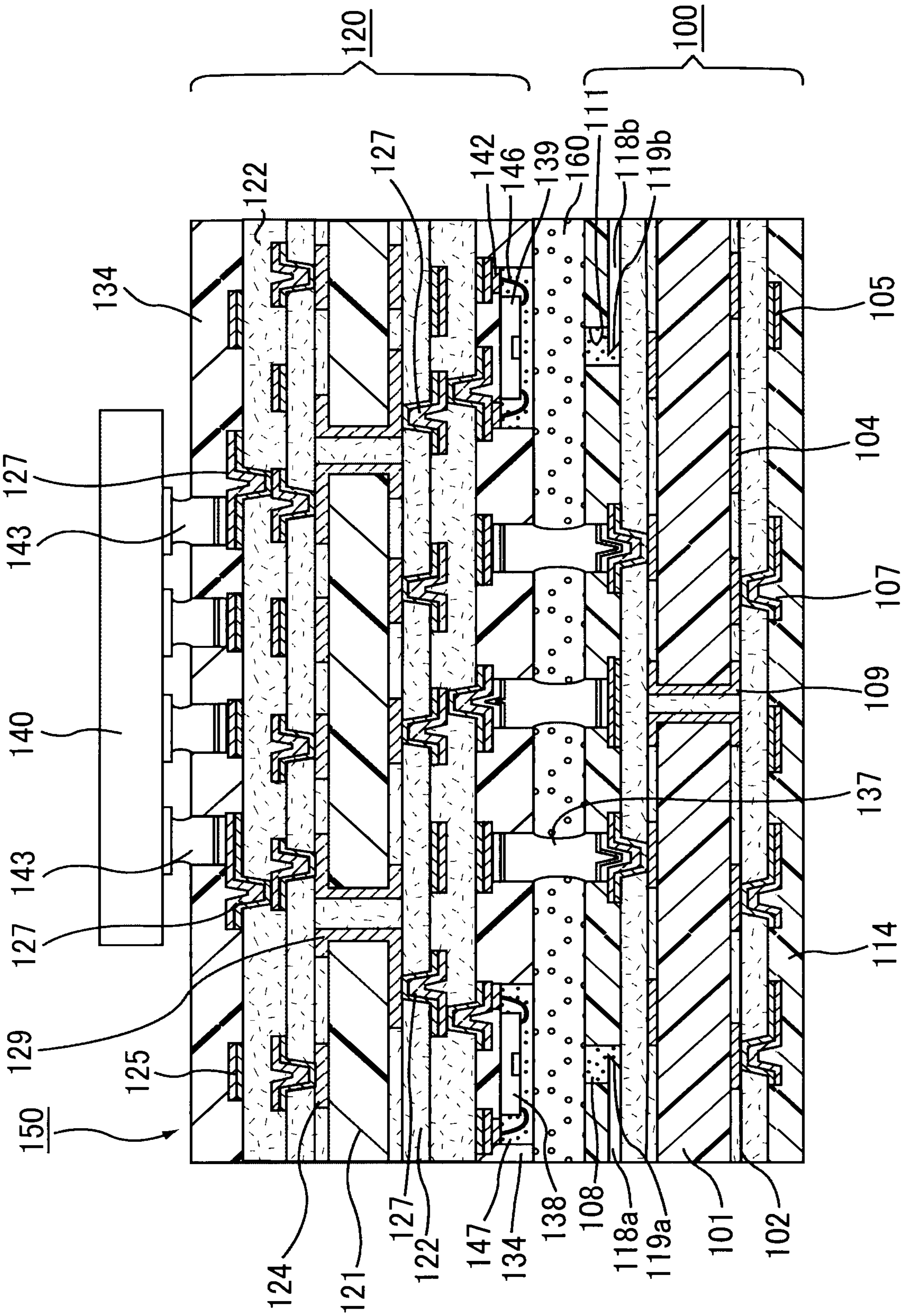

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FIG.2

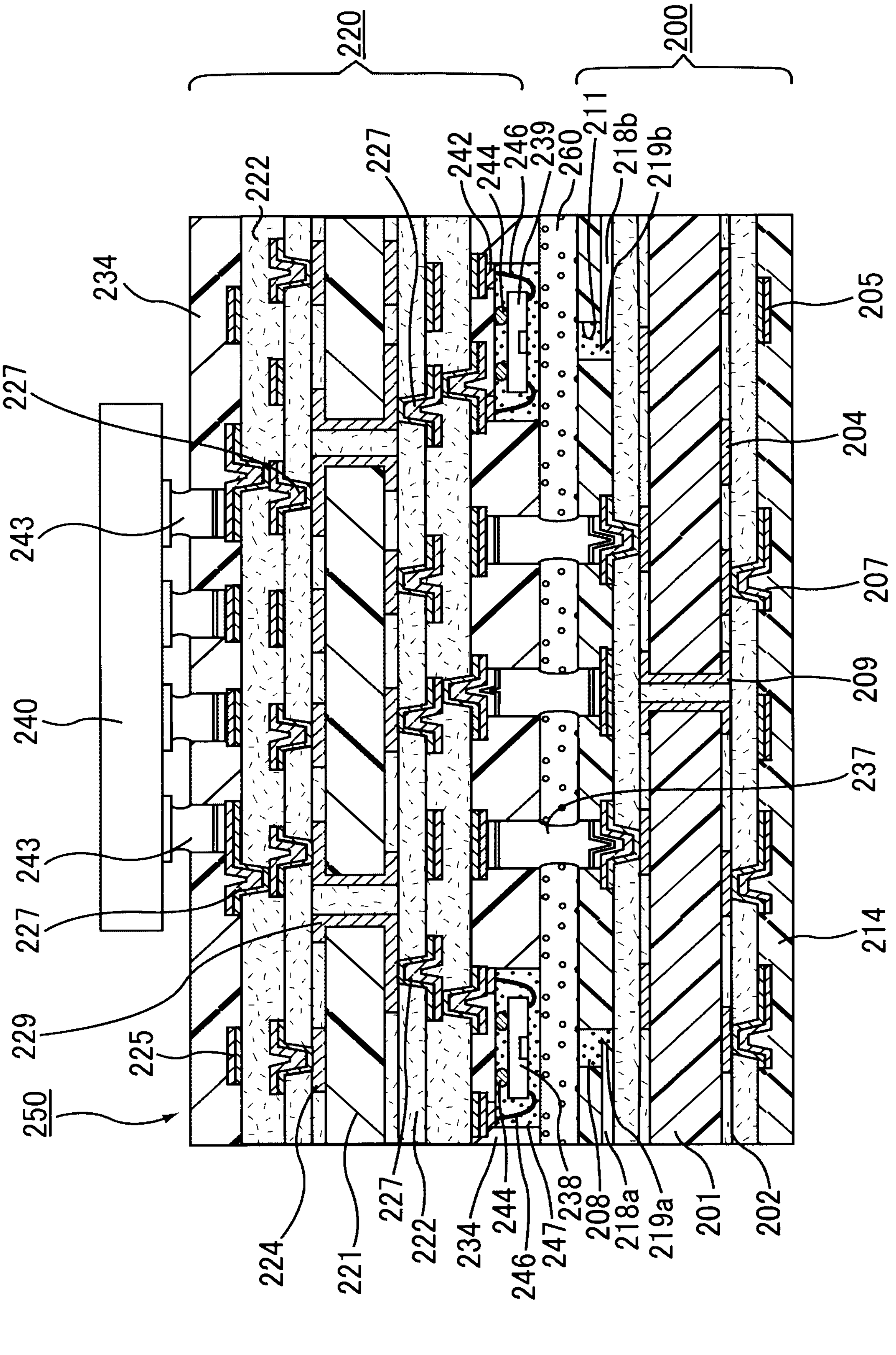
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FIG.3

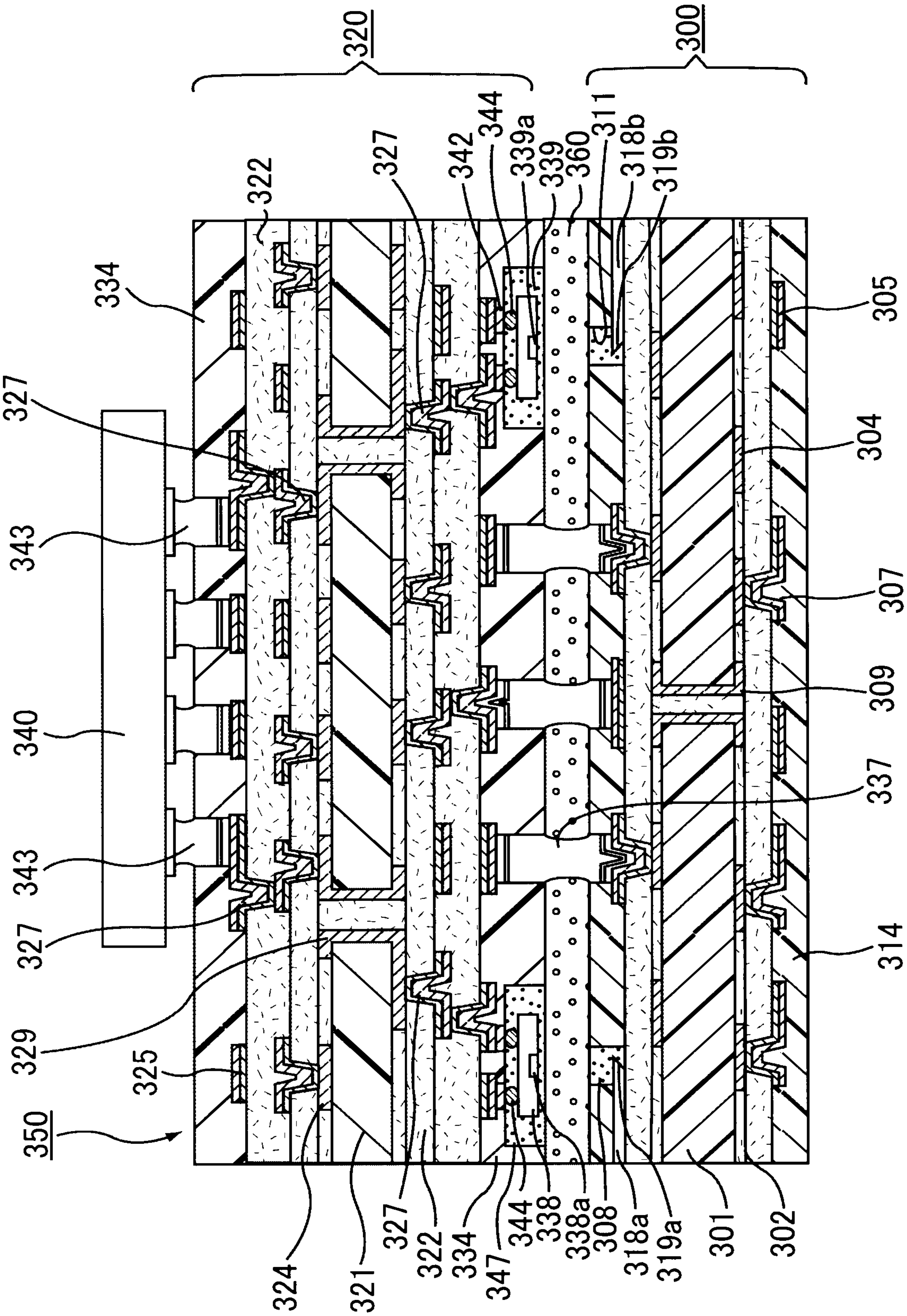
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FIG.4

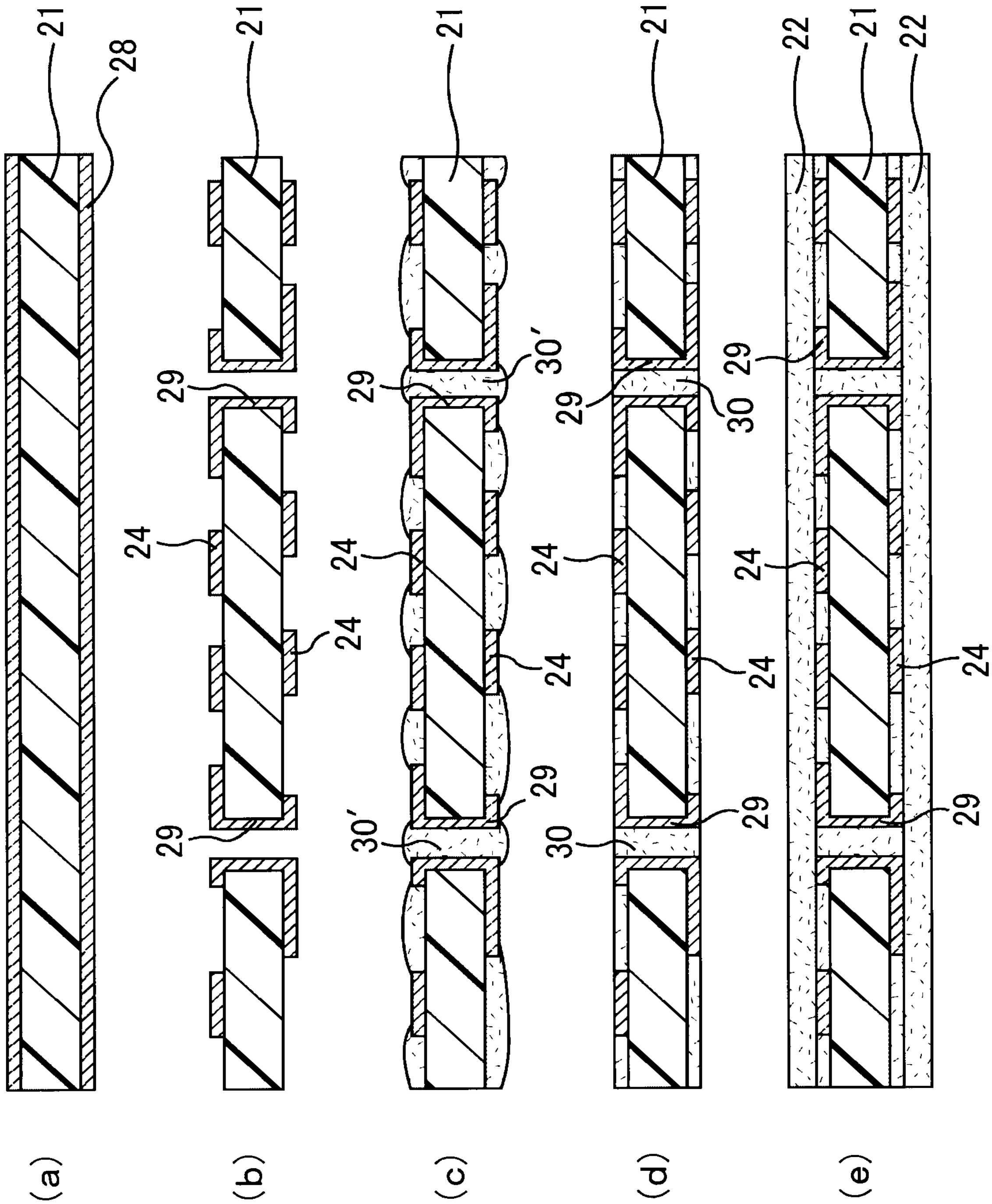


FIG.5

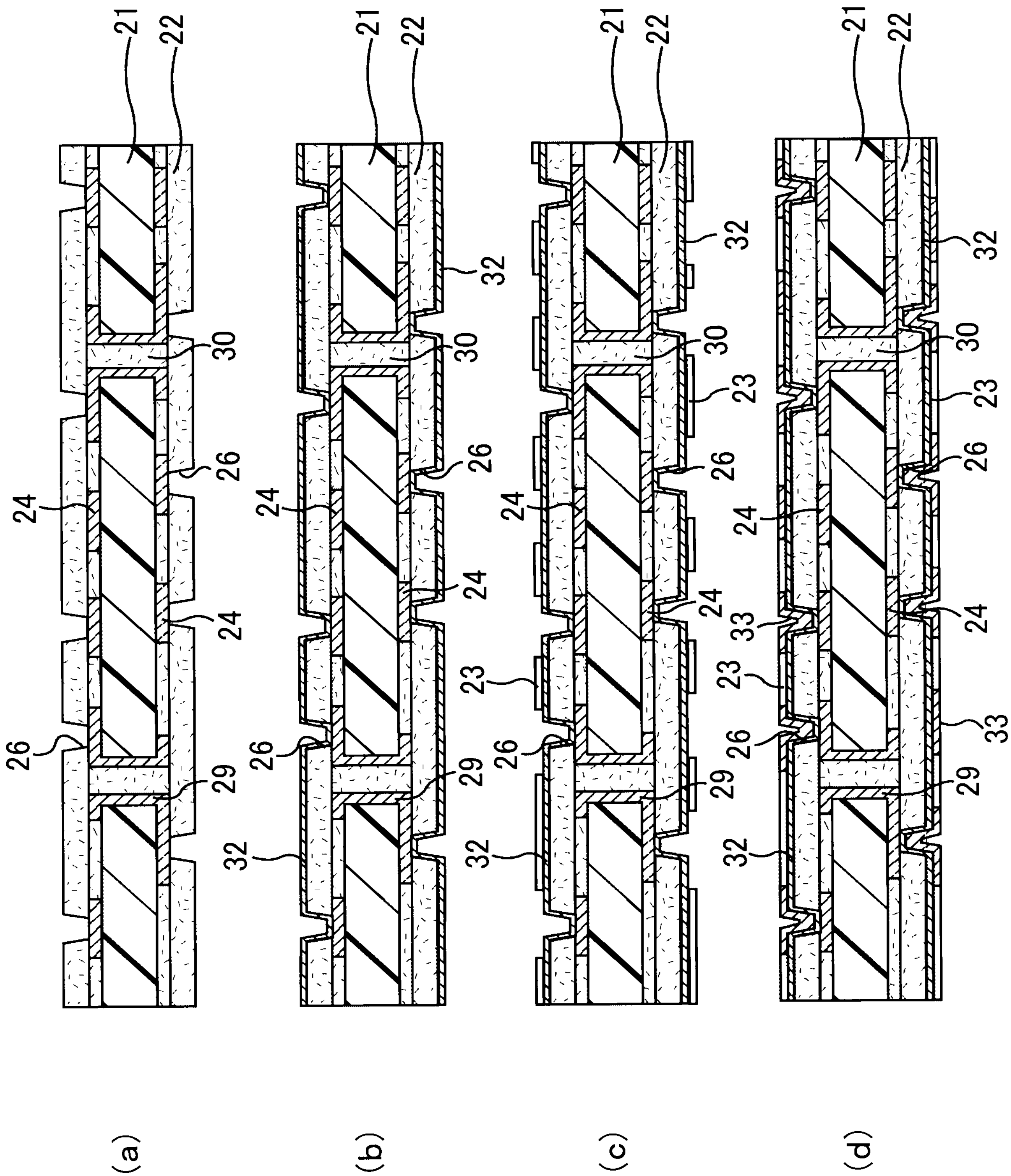


FIG.6

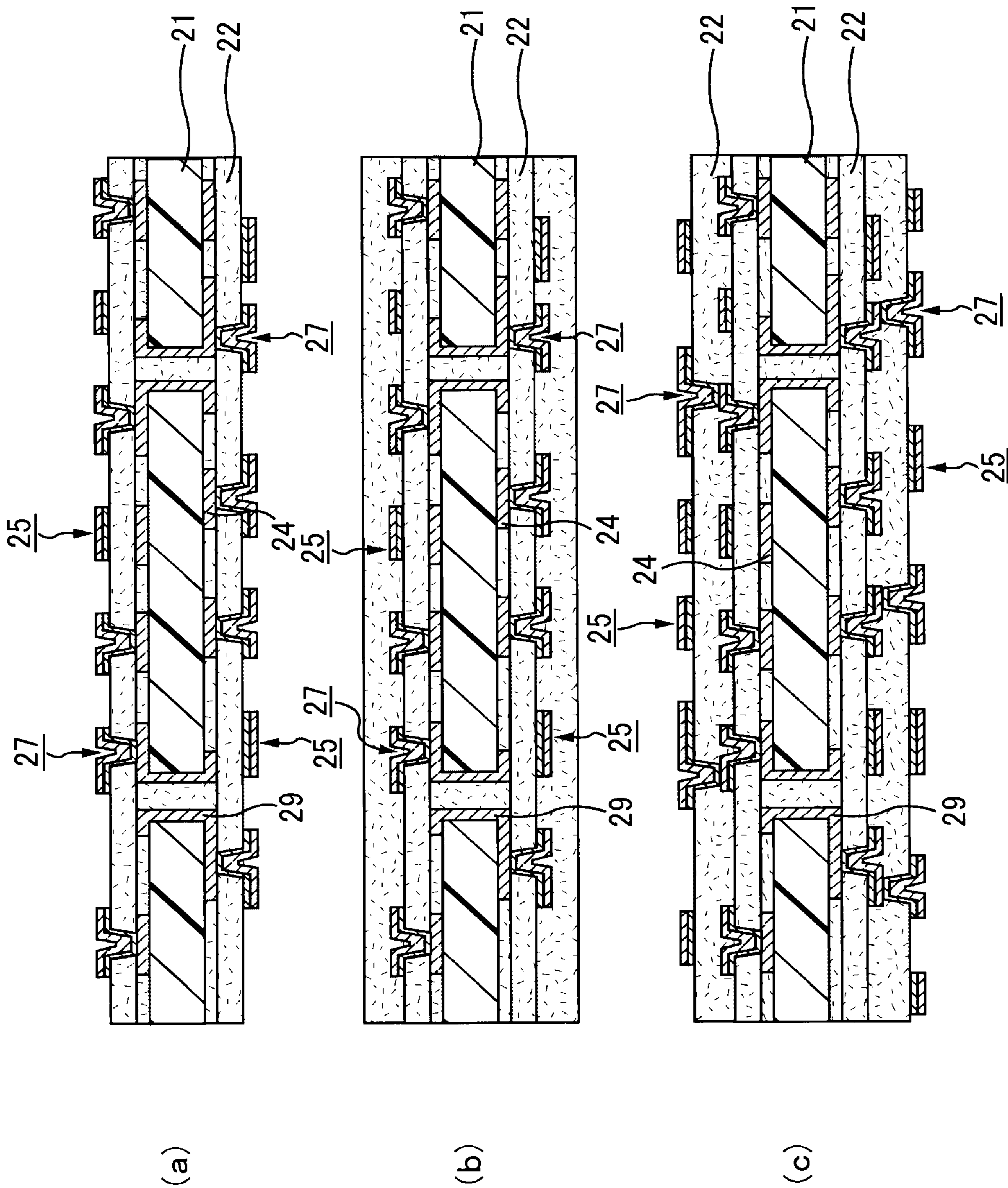


FIG.7

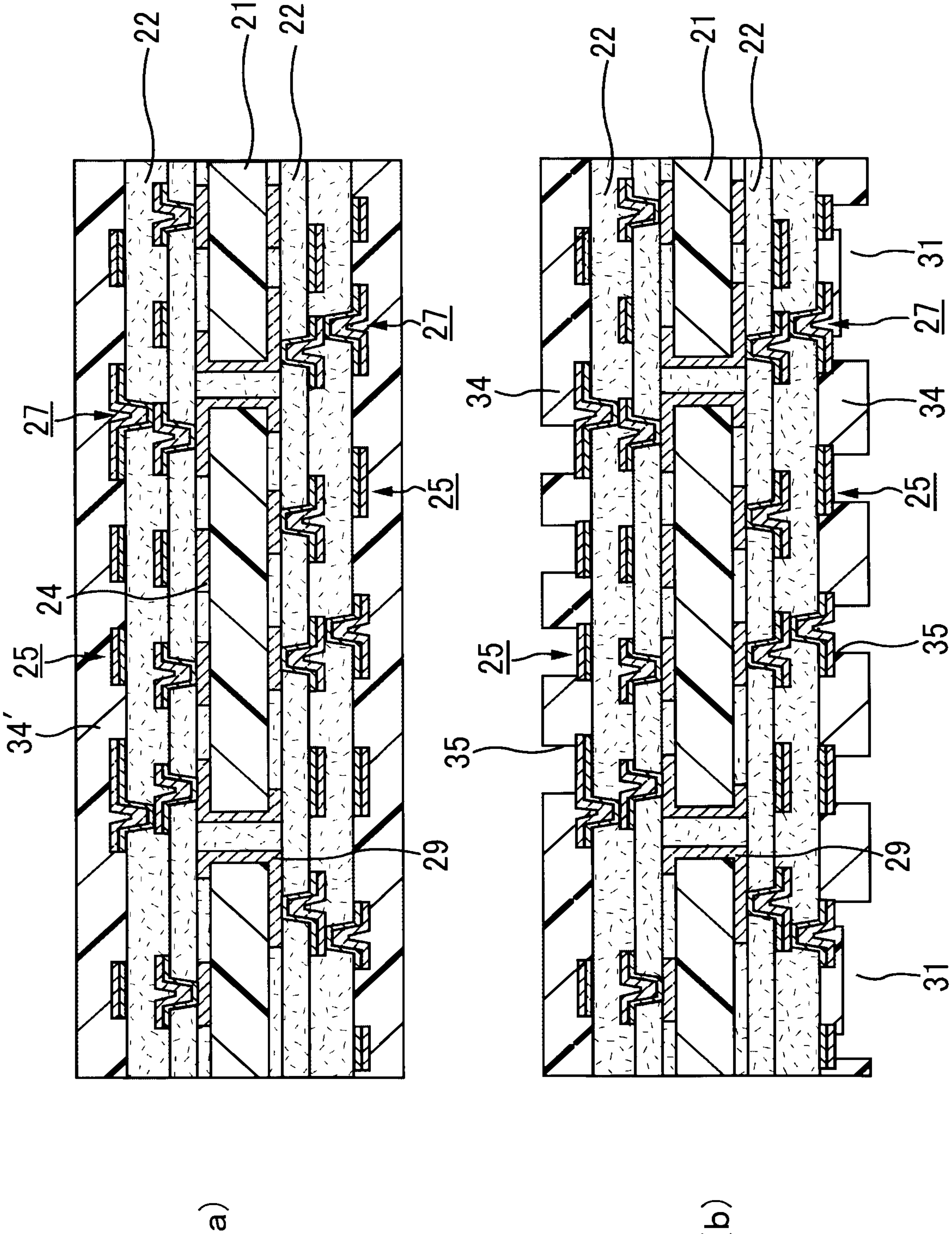


FIG.8

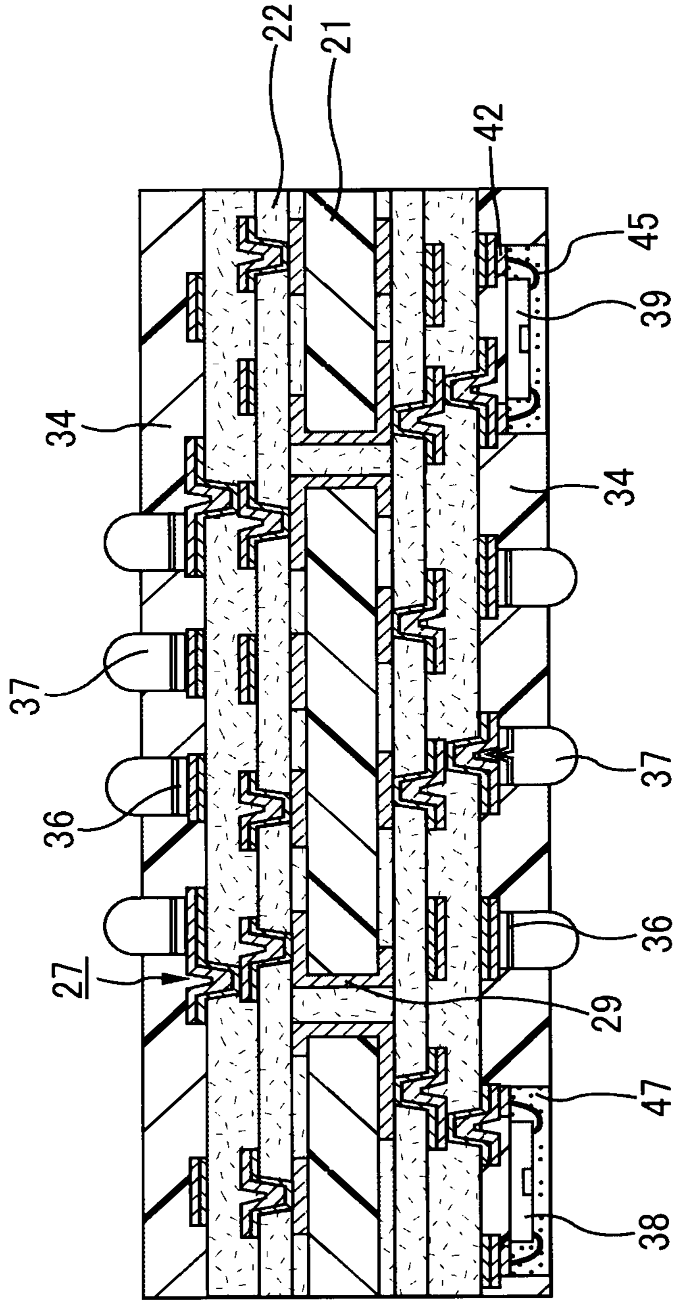


FIG.9

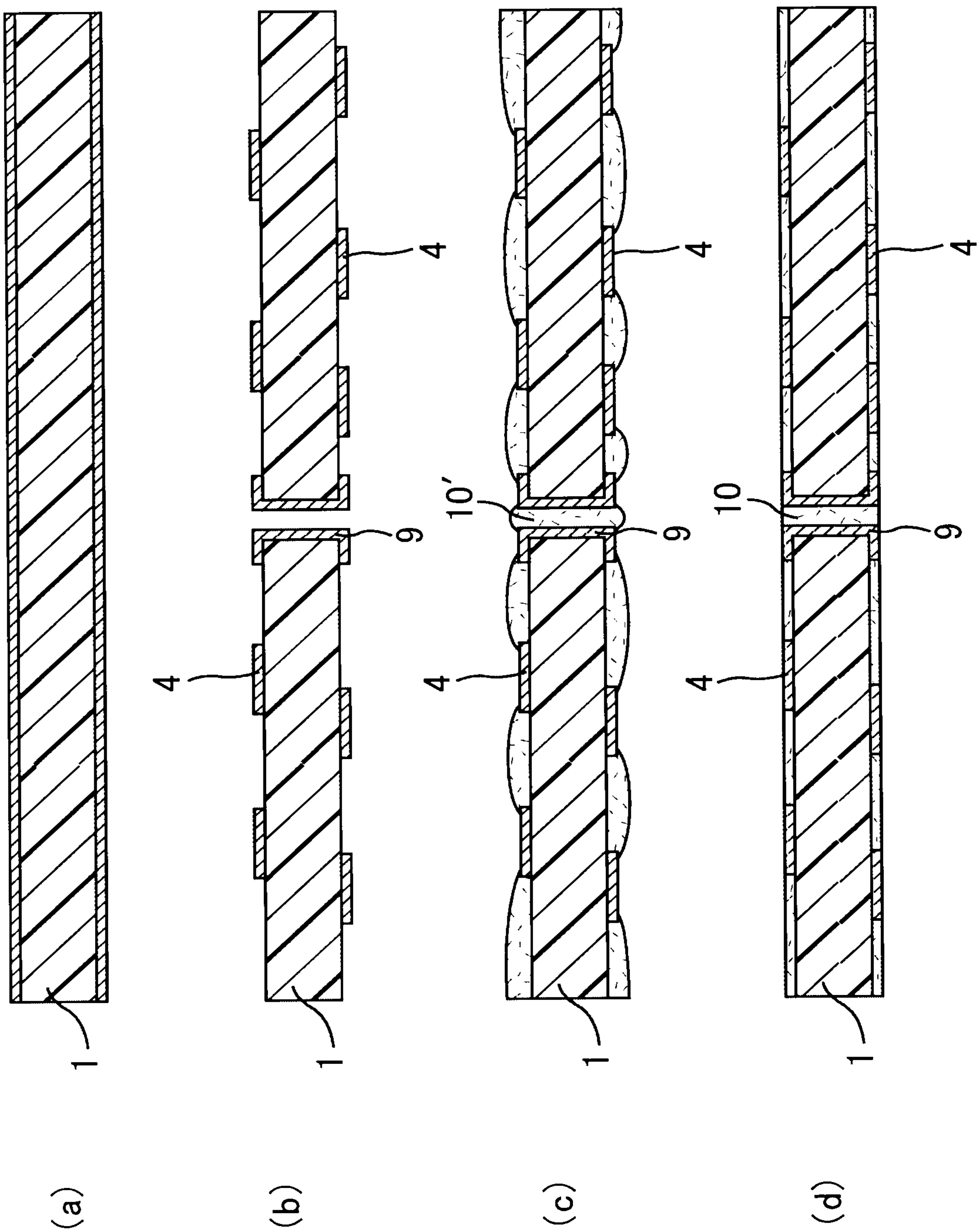


FIG.10

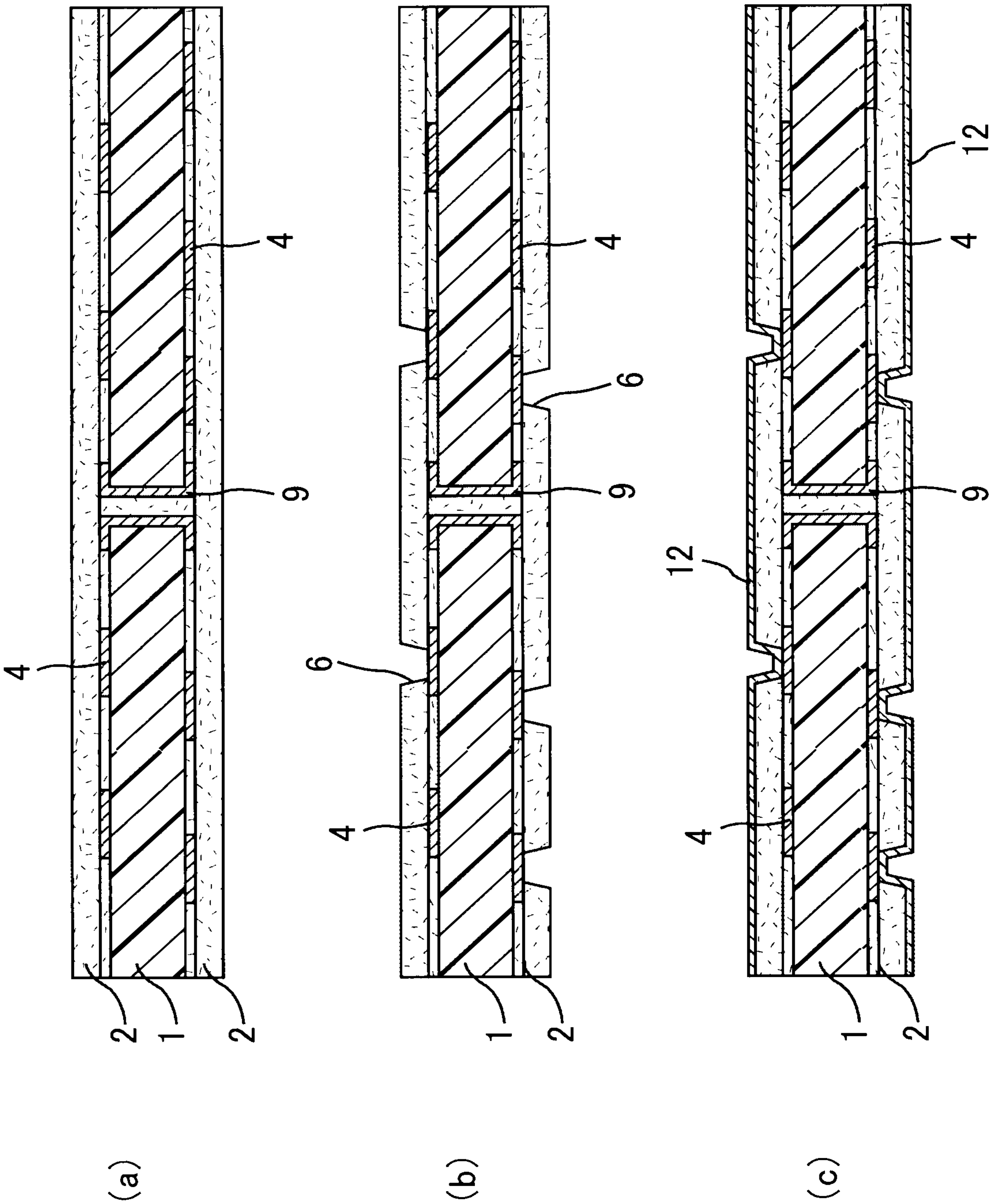


FIG.11

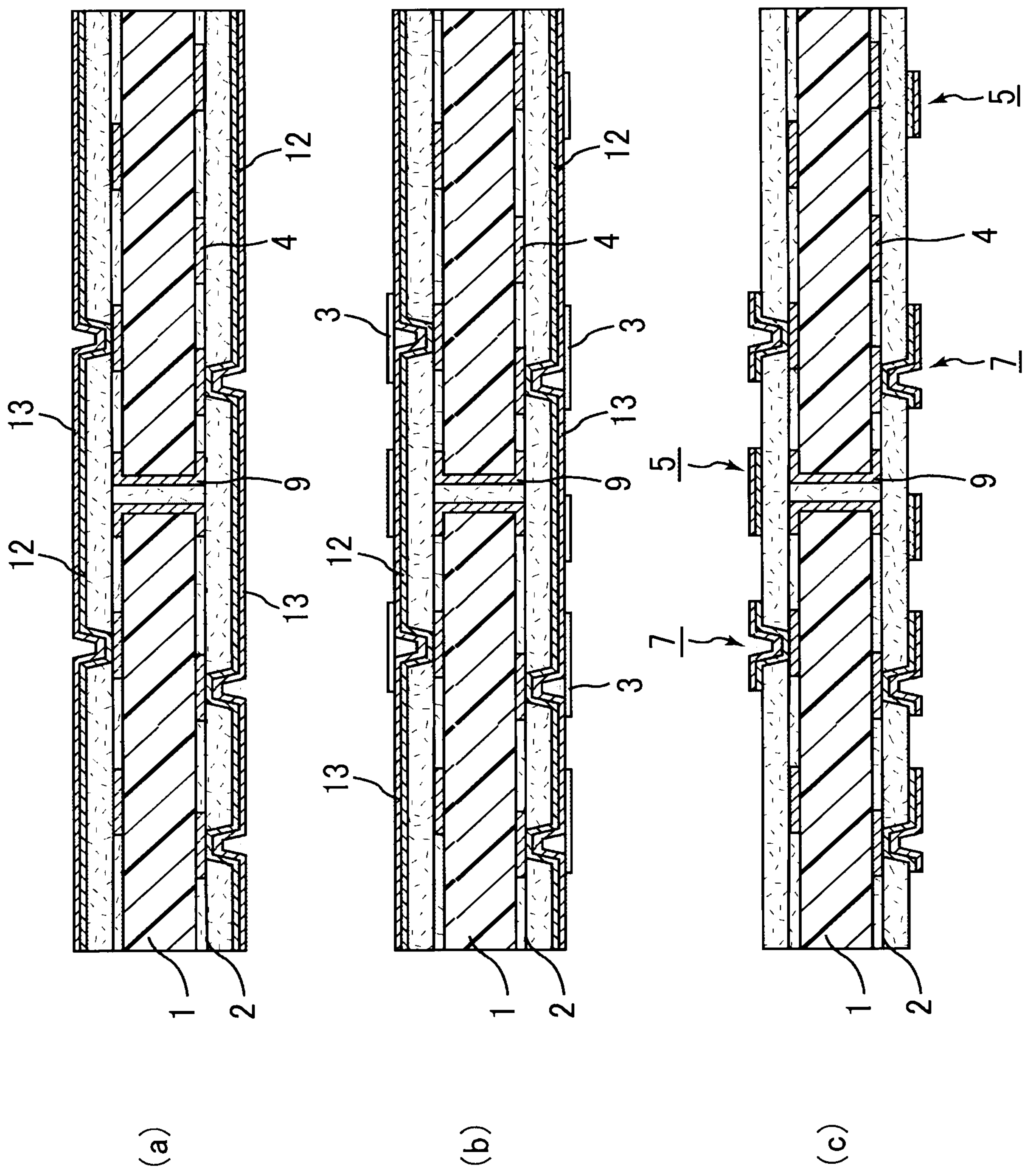
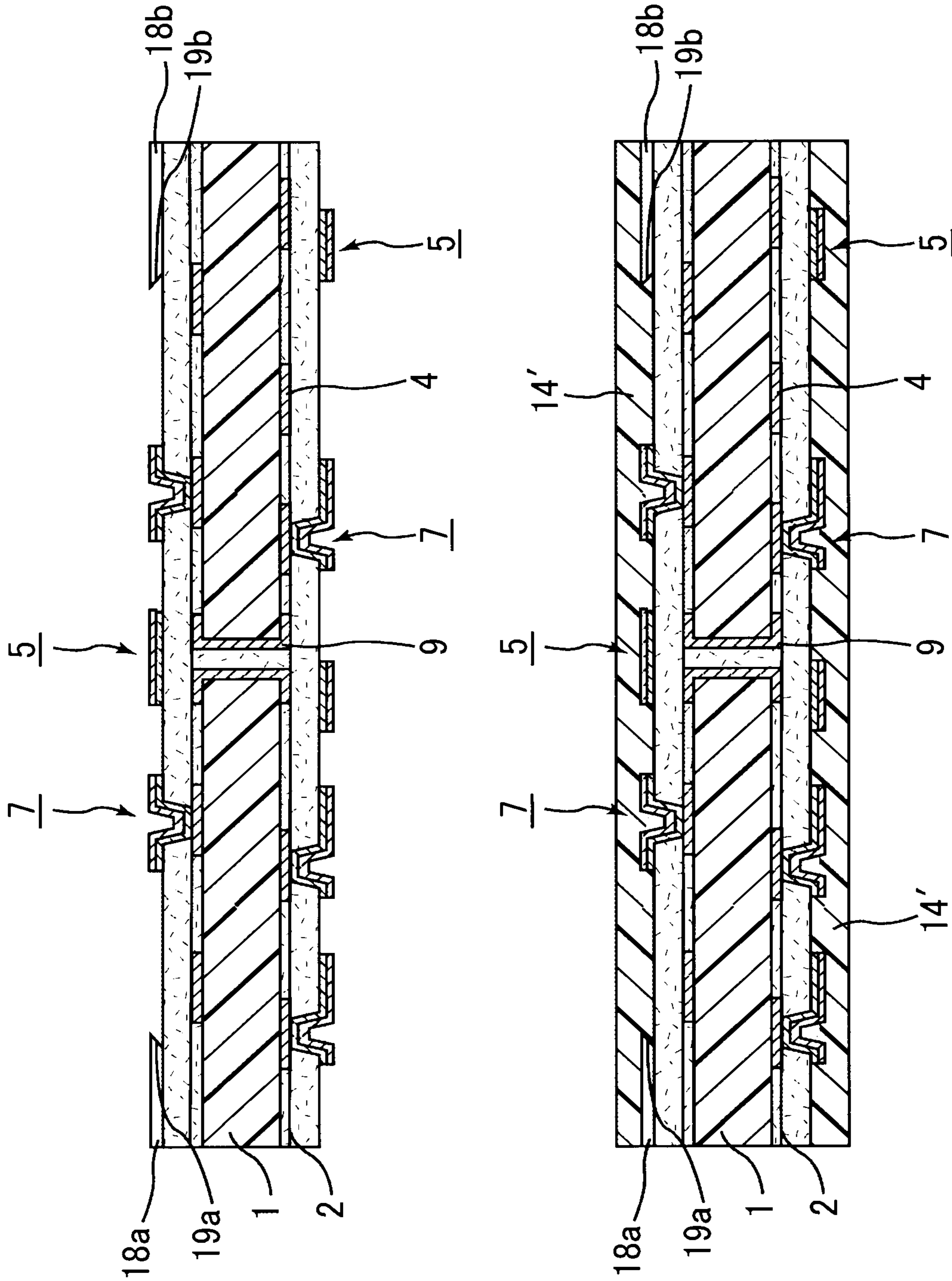
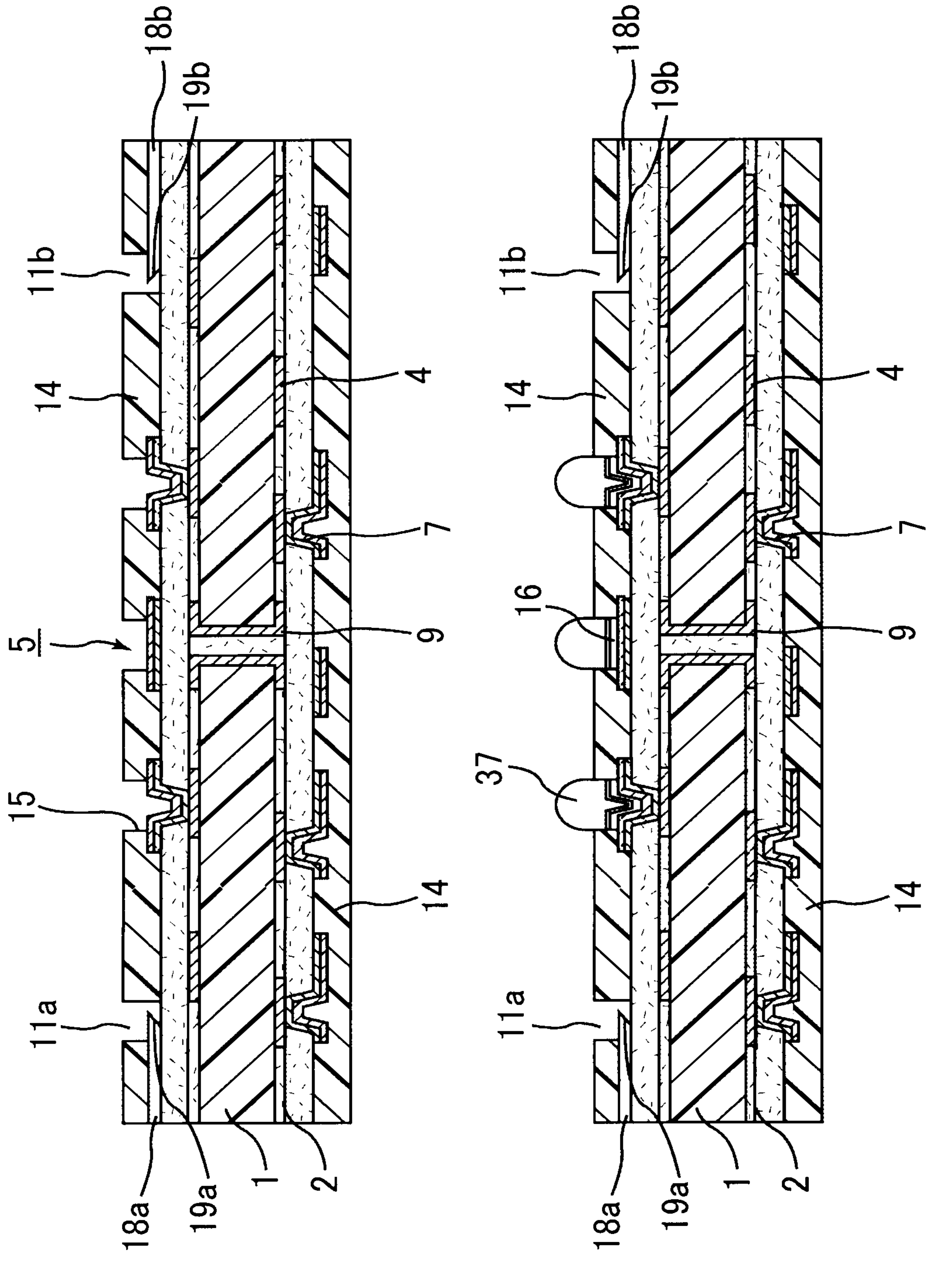


FIG.12



(a) (b)

FIG.13



(a)

(b)

FIG.14

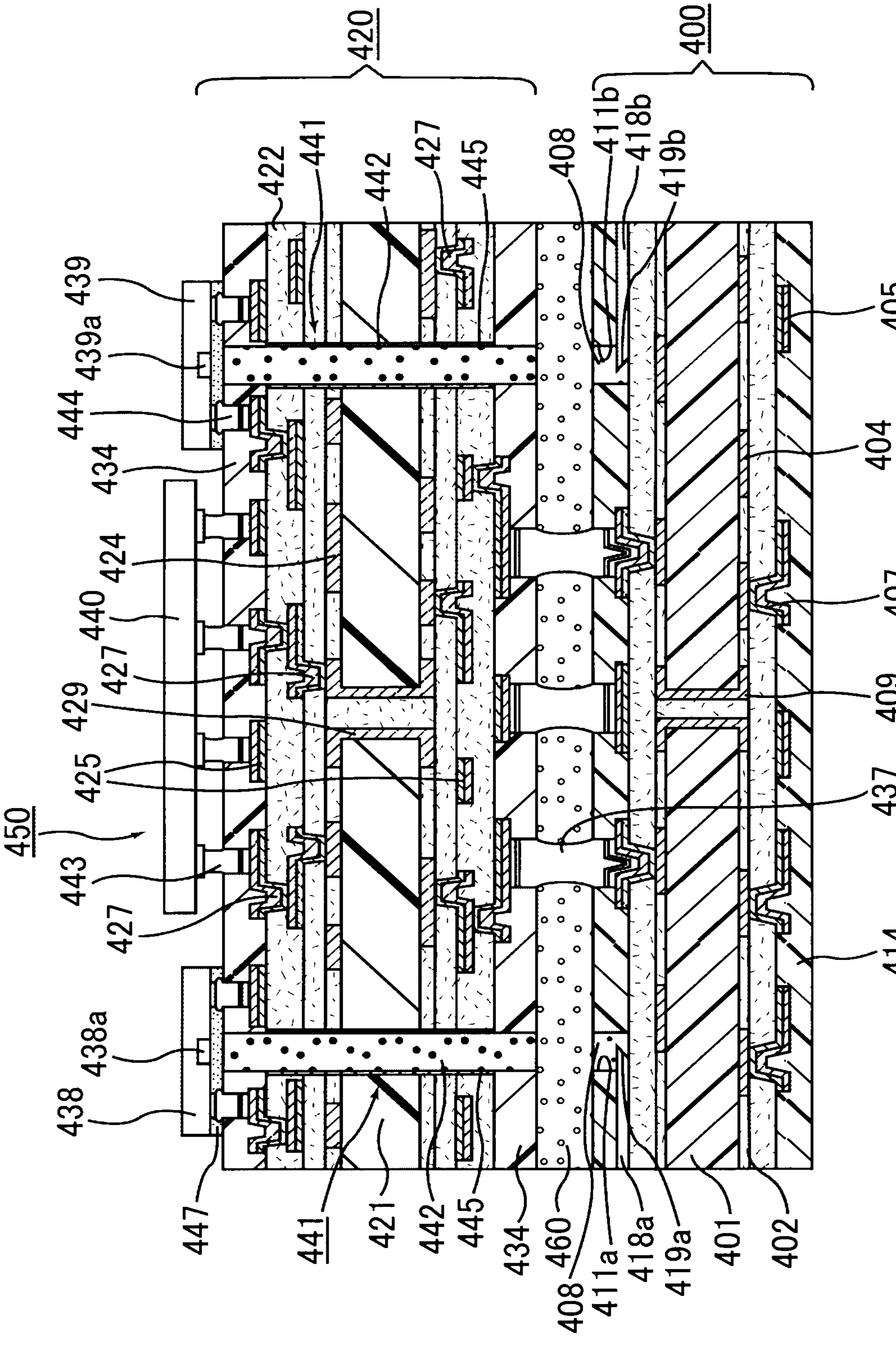


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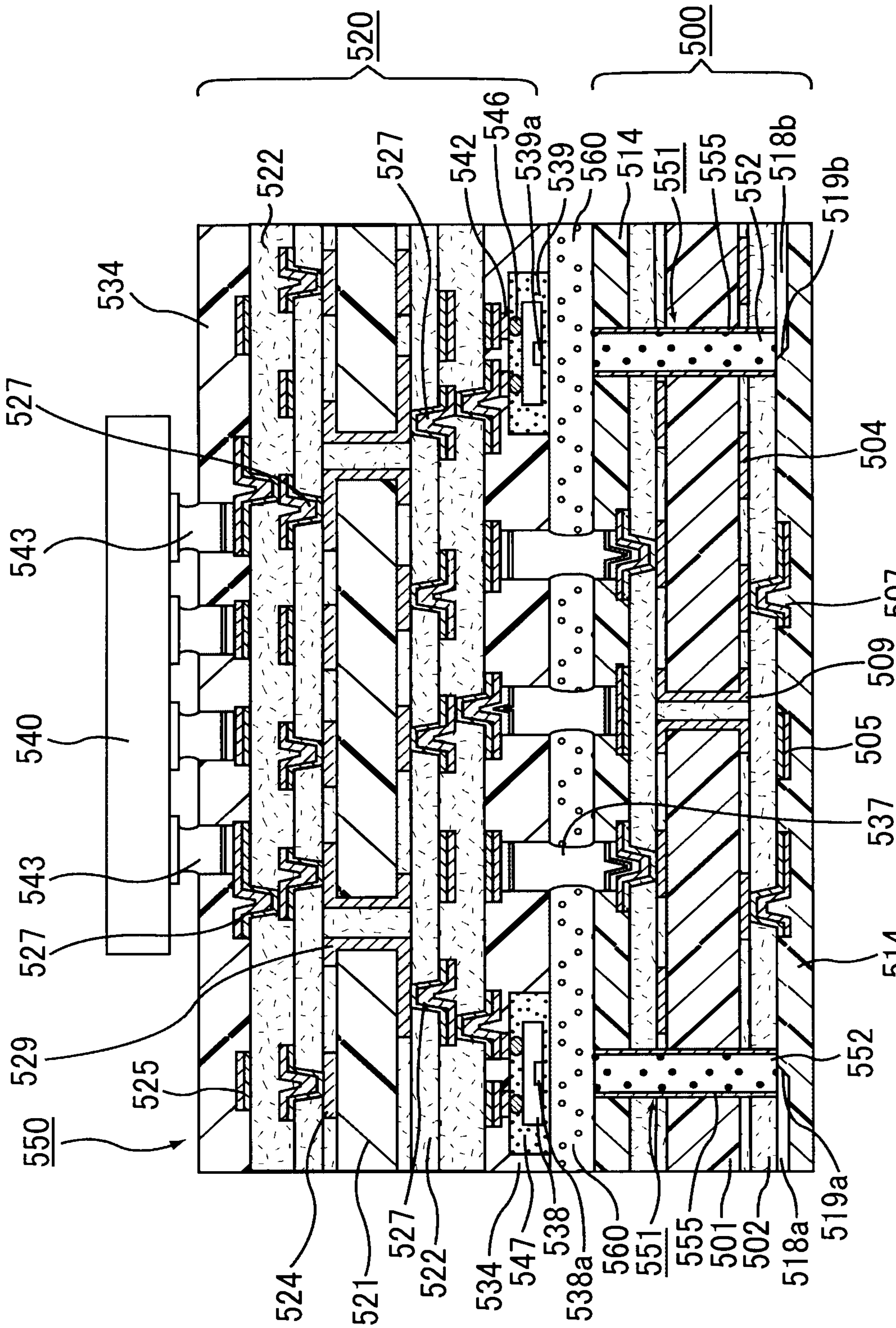
FIG.15



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